A36

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1952

EAST MALLING RESEARCH STATION

Near MAIDSTONE
KENT

1st October, 1951 to 30th September, 1952

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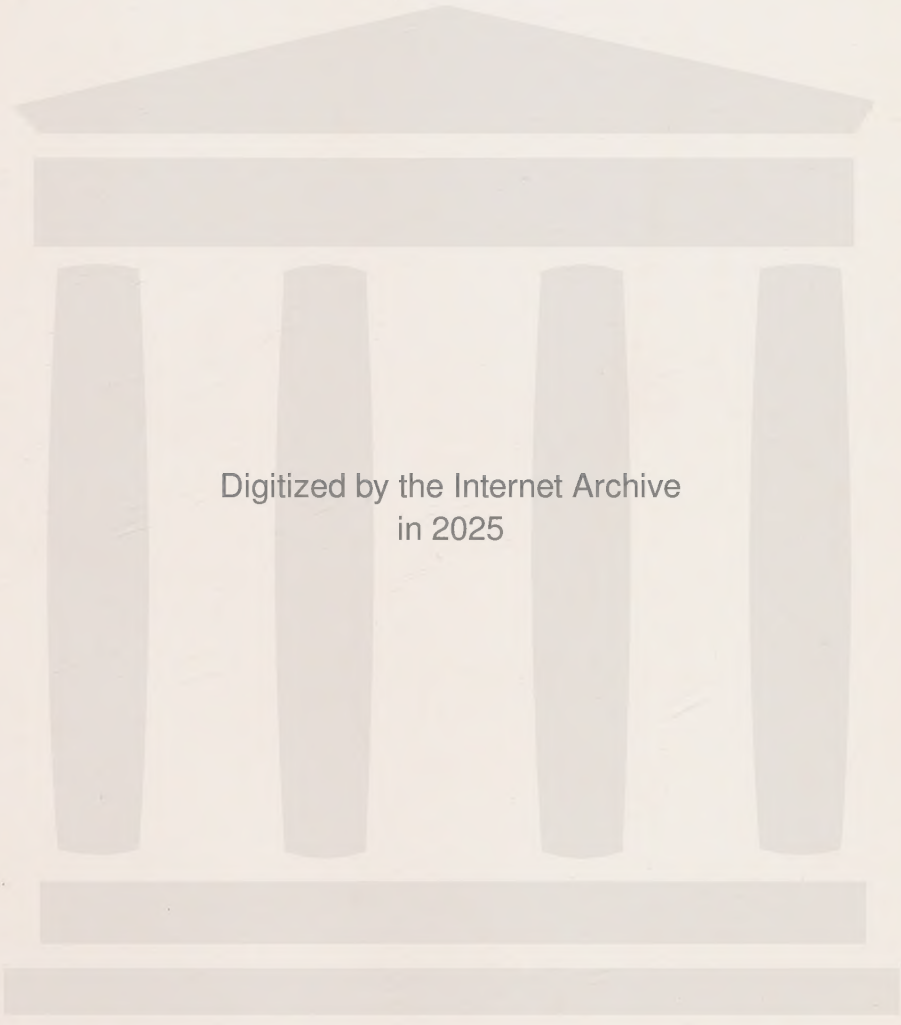

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THE PLANTING OF A BLACK MULBERRY TREE TO COMMEMORATE THE ACCESSION AND CORONATION OF H.M. QUEEN ELIZABETH II.

On 25th March, 1953, in the presence of more than 250 Members and Staff, a black mulberry tree was planted in the round bed opposite the original laboratory and office of the Research Station in Great East field to commemorate the accession and coronation of Her Majesty Queen Elizabeth II; the tree had been propagated from material collected by the late Dr. R. C. Knight from the famous tree in the Chelsea Physic Garden, which was probably planted about 1673. The ceremony was carried out in delightful weather by Mrs. F. R. Tubbs, at the request of Mr. R. J. Garner, Chairman of Staff Council, under the watchful eye of Mr. T. N. Hoblyn who, in thanking Mrs. Tubbs on behalf of the Staff, presented her with a stainless steel garden trowel as a memento of this very pleasant and memorable occasion.

A36

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTIETH YEAR)

1952

EAST MALLING
RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1951 to 30th September, 1952

Published May, 1953

The correct abbreviation of the title of this Report is :—
Rep. E. Malling Res. Sta. for 1952 (1953).

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ERRATUM

East Malling Research Station Annual Report for 1951 (published June 1952).

' Raspberry varieties in Great Britain ' (C. A. Wood). Page 88, under ' Malling Landmark ', para. 2, last two lines :

Delete—' The fruit is generally suitable only for the jam market ' *and*

Substitute—' Experience with this variety has indicated that its fruit quality does not meet the full requirements of either the fresh fruit, canning, or jam markets '.

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VISITORS.

Tours of the Station are arranged by appointment on Tuesday and Thursday afternoons. Visitors with special interests are received by appointment on the mornings of these days and may then join the general tour later if they wish. Wednesdays and Fridays are reserved for visiting research workers who also should make an appointment to ensure that a useful programme for the visit can be prepared.

All visitors wishing to see the work of the Station should go to the Enquiry Office at the Research Laboratories.

Visitors coming by road should take the turning to East Malling, opposite " The Bull ", Larkfield, on the main London-Maidstone road. The entrance gate to the Research Station is on the left, opposite the " King and Queen " in East Malling.

Bus Service : From Maidstone by the Maidstone and District Motor Services Limited, every 20 minutes from Maidstone to East Malling.

Passenger Station : East Malling Halt (British Railways, Southern Region).

Goods Station: Aylesford (British Railways, Southern Region).

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THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

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FOREWORD

Though the form of the Annual Research Report remains the same, its contents vary in emphasis from year to year. Growers' Bulletins, to be found in Part IV, are more numerous this year than last, and the Research Reports in Part III fewer, but once again they provide a cross-section of the many and diverse lines of research in progress. A fuller picture of the research programme will be obtained from the reviews of research in progress in Part II of the Report. Considerations of space limit drastically the amount of detail that can be given, but the reader will find much of interest in them, and in the accounts of the experimental farm, nurseries, and greenhouses, given in Part I.

It is particularly desired to thank all those, too numerous to mention individually, who have assisted the Station during the year ; fuller, but still necessarily incomplete, acknowledgements are made in the Administrative Report, which was published in April.

Of direct interest to nurseryman, grower, and research worker, has been the release, for test by research centres at home and overseas, of the Malling-Merton series of apple rootstocks, resistant to Woolly Aphid; these originated in collaborative work led by Sir Ronald Hatton at East Malling and by Mr. M. B. Crane at the John Innes Horticultural Institution. Five rootstocks of this series, selected as meriting widespread trial in Britain on the basis of their nursery and field performance, have now been released to large-scale stoolbed raisers ; detailed descriptions will be found on pp. 55, 64, and 169.

Part I

*THE EXPERIMENTAL FARM**

By F. H. VILLIERS, with contributions from T. V. DIXON and M. M. MACNEILL

This year's notes begin with a brief description of the way in which the land on the experimental farm is used. This may give those who are not conversant with the lay-out, some idea of the scale of operations. The whole area occupied by the Research Station is 363 acres in extent, of which 40 acres are occupied by buildings, roads, woods, and water. The remaining 323 acres are used as follows :

Top fruit in bearing	72 acres.
Top fruit coming into bearing	28 acres.
Newly planted top fruit	22 acres.
Soft fruit	13 acres.
Nursery and stoolbeds	25 acres.
Small-scale laboratory trials	33 acres.
Arable land in preparation	130 acres.

The arable land is either being got ready for future trials, being rested after having been used as a nursery, or lies in that part of the estate which, for various reasons, is unsuitable for experimental use. All the open land is farmed on a simple rotation, designed to raise the level of fertility and restore uniformity.

The top fruit consists of apples (86½ acres), pears (8 acres), plums (10½ acres), cherries (14 acres) and walnuts (3 acres). More than half the apples have been planted since 1945, but so far post-war plantings of other top fruits have been on a small scale. The 13 acres of soft fruit consists of strawberries (5¼ acres), raspberries (4¾ acres), blackcurrants (1½ acres), and loganberries (1½ acres). In the nurseries there are 10½ acres occupied by stoolbeds and bedded stocks, 9¾ acres by fruit trees, including rootstocks lined out for budding, and 4¾ acres by soft fruits. The area devoted to laboratory trials includes between 40 and 50 scattered areas of mixed fruit plants required for specialized work which cannot be carried out under orchard conditions.

The year 1952 was on the whole favourable for growth and cropping. The low summer rainfall prevented some of the fruit developing to perfection, but most crops were heavier than for some years and the quality, apart from some varieties of plums and cherries, was undoubtedly a big improvement on 1951. The season was particularly early ; after a very wintery spell at the end of March and during the first week of April, the weather became very hot at Easter, so that all fruit blossom opened very quickly, and continued warm throughout the summer, picking dates being about 16 days earlier than usual. Picking started on Royal Sovereign strawberries on 28th May, Early Rivers cherries on 7th June, and the earlier raspberries on 24th June.

Experimental orchards.

Top fruits.

Apples.—The 1952 crop of apples amounted to 12,946 bushels (40 lb. to a bushel) in all ; this was 200 bushels more than in 1951 and of much better quality. Fruit colour and finish was exceptionally good, possibly better than any previously experienced at the Research Station. Considering the long dry spell in the early summer, fruit size was on the whole surprisingly good, though here and there the fruit came small. Red spider control was more successful than in the previous season, and there was little fruit with that dull colour often associated with an attack by this pest. Larger yields in the post-war Church Fields and Larkfield plantations more than made up for the areas recently grubbed.

The crop of Cox's Orange Pippin (2,849 bushels), was one of the heaviest in the Station's history. All plantations bore satisfactory crops of beautiful-looking fruit, though some was rather small. A little more rain in early summer might have increased the market value of the crop. All the older plantations of Worcester Pearmain were fruit thinned in 1952 ; although fewer apples were picked, the quantity marketed was rather more, 3,426 bushels as compared with 3,163 bushels in 1951. Despite thinning, however, some of the fruit from the shallower patches of soil on Kiln Field was very small

* For the calendar year 1952.

again because of the dry summer. On the younger plantations where there is a good depth of soil and, as yet, little root competition, both size and quality were excellent. Jonathan at 7 years old in the rootstock trial on Church Fields averaged approximately $1\frac{3}{4}$ bushels per tree and Ellison's Orange in the same plantation averaged just over 2 bushels per tree. The Jonathans have responded particularly well to the light pruning practised in this trial and the fruit sells well on its colour, but Mildew has given us a certain amount of trouble.

The crop of Bramley's Seedling was disappointing, only 1,530 bushels as compared with 2,500 bushels in 1951 from the same number of trees. Both blossoming and fruiting were very patchy, some trees bearing almost a full crop, while others carried only a few fruits and even those were small. Lane's Prince Albert, our other main culinary variety, gave a moderate crop (660 bushels) of good quality fruit, slightly less than in 1951. Owing to the removal of most of the Grenadier pollinators, due to overcrowding, some of the Lane's have now been frameworked to Howgate Wonder, a cooking apple which by reason of its late season may be more profitable than the early Grenadiers. This, however, remains to be seen.

Pears.—As with apples, the younger plantings of pears are now beginning to replace the older ones grubbed at the end of the war. Thus the total crop this year was 647 bushels (48 lb. to a bushel) as against 378 bushels in 1951 and only 200 bushels in 1950. The Williams' Bon Chrétien in the double working experiment, planted in 1941, averaged 1 bushel per tree for the first time. This may not seem a very heavy crop, but it must be remembered that, as with so many of our trials, these trees include both good and bad experimental combinations.

Cherries.—Cherry growers in most districts will long remember 1952 as a year of exceptionally heavy crops of almost all varieties. We marketed 3,265 halves (24 lb. to a half sieve). Even though some of the poorer varieties in the collection were not harvested, this was three times the 1951 crop and 50 per cent more than the previous highest crop in 1949. This year on the 24-year-old rootstock trial all the three varieties, Early Rivers, Bigarreau de Schrecken, and Turkey Heart gave similar yields, whereas in the past Early Rivers has usually cropped considerably more heavily than the other two. The total yield from this 6-acre plantation was 2,569 halves or 428 halves per acre. The trees in the variety collection also yielded heavily. Owing to the heavy crops and lack of rain, however, fruit size was extremely poor, and prices were so low that some of the white varieties and the smaller black sorts were not worth picking.

Plums.—1952 was a year of heavy plum crops in many parts of the county ; here, Victoria and Ontario cropped particularly heavily, although there did not appear to be any more blossom than usual.

The total plum crop was 3,054 halves (28 lb. to a half sieve), 525 halves more than in 1951 and the heaviest since 1947. Victorias accounted for nearly half the crop, but, where the fruit was not thinned, were a very poor sample. Where the fruit was thinned to 2 in. apart, it was much larger but, as was apparent at picking time, wider spacing would have given better results. Ontario, on the other hand, appear to thin themselves, and although no thinning was done the fruit was of satisfactory size. This is a big point in favour of this variety in these days when fruit thinning is so expensive. The trees in the gage plum variety collection and rootstock trial also yielded well, but not quite so heavily as in 1951.

Peaches.—The 4-year-old bush peaches in Bradbourne Gardens bore their first real crop. Altogether over 5,000 fruits were sold from these and the 7-year-old wall trees. The quality of the fruit, from the wall trees in particular, was excellent.

Soft fruits.

The only black currants remaining were 1 acre in a straw mulching trial and $\frac{1}{2}$ acre being used for Black Currant Midge investigations. All varieties gave useful crops, averaging approximately $2\frac{1}{2}$ tons per acre, which is considerably more than they have done for several years past.

The farmyard manure applied to our raspberry cropping trials seems to have paid a good dividend ; yields were again heavy in spite of the dry spell at picking time. The total crop was just under 8 tons, almost equal to last year's crop from a slightly larger acreage and in a much wetter summer. Much of the $4\frac{3}{4}$ acres of raspberries contains young seedlings and hybrids which do not contribute much to the total crop. Our mature raspberry plantations, about $2\frac{1}{2}$ acres, produced nearly 3 tons per acre.

Strawberries suffered from the very dry spell just before and during picking, except on an irrigated plot where they did very well. Elsewhere many of the plants wilted badly and much of the fruit shrivelled up and was not worth picking. Attacks by ground beetles also reduced the amount of saleable fruit, by chewing large pieces out of the swelling fruit, which was thus made quite useless, and by puncturing many other fruits which subsequently rotted. We harvested 3 tons in all from a rather smaller acreage than in 1951.

The new loganberry trial bore its first small crop—$12\frac{3}{4}$ cwt. from 1·3 acres.

Fruit marketing.

As already stated, the quality of our fruit was much improved this year, but too much of it was still too small. As imports increase and more of the post-war plantations of dessert apples in this country come into bearing, competition becomes increasingly keen. No apology, therefore, need be made for emphasizing once again the importance of quality, size, and presentation of the fruit. In the past, $2\frac{1}{4}$ in. to $2\frac{1}{2}$ in. fancy grade dessert apples have, on the whole, sold readily, but this season, except for Cox and the late varieties, only $2\frac{1}{2}$ in. to $2\frac{3}{4}$ in. and slightly larger sizes made really remunerative prices. On the London markets a gradually increasing number of non-returnable containers is being used ; all salesmen, however, emphasize that the quality of the fruit must be commensurate with the package.

Increased cold storage capacity again helped us to regulate the marketing of Worcesters. Fruit stored and marketed after the peak period of the Worcester crop had passed sold much more readily than that marketed at the height of the season. This store was later filled with Bramley's Seedling and Lane's Prince Albert for gas storage. In 1951 these apples were graded before storage but were not wrapped ; as there was no loss from scald or other causes it was decided to take the risk of not wrapping again this year. Our second store was filled with Cox's Orange Pippin for cold storage until Christmas, and the third store with other late keeping dessert apples.

Marketing cherries and plums was a difficult job, owing to the heavy crops and poor size of most of the fruit. As many as possible of the better quality cherries were sorted and marketed in 8-lb. chips ; but the whole crop could not be treated in this way, and the remainder were sent in half boxes, some to the Midlands in an effort to avoid the congestion in local markets. All Victoria plums were sold for canning but gage plums were sorted and marketed in 12-lb. chips, some of these, too, being sent to the Midlands.

Fresh plantings and grubbings.

With the exception of a small plum rootstock trial on Egham Field, most of the planting done in the autumn of 1952 was for small-scale laboratory trials. These required some $2\frac{3}{4}$ acres on Newgates and Egham Fields. A single row of 42 Victoria plum trees has been planted on Park Farm for studies of branch breakage in relation to tree form ; $1\frac{1}{2}$ acres of Victoria plums on Deadman Field, formerly in a stembuilding trial, will be grubbed in the spring of 1953. In the same field further thinning is being done to allow room for the trees in the gage and plum variety collection to develop their natural habit. The windbreak of Kent Bush plums on the east side of this field is to be removed for the same reason.

On Church Fields all the trees on M.I and M.V in the manurial trial (C.2) have been grubbed, leaving only a single tree of Cox's Orange Pippin on M.XII in each plot. On the adjacent plot (C.3), 50 trees frameworked with new seedling apple varieties were removed ; the more promising of these seedlings are now being grown elsewhere. In Great East Plantation the 32-year-old apple double-working trial (G.16) has been cleared. On Merryweather the remainder of the black currants and the first nine rows of apples adjacent to them are also to be grubbed. The shortage of land is now so acute that any plantations no longer of experimental value must be cleared, and for this reason it has been decided to start clearing the cherry variety collection in Egham Field. Another collection is now well established at the Kent Farm Institute at Borden, and a start is being made on a new collection of virus-free varieties, which will eventually be planted at the National Fruit Trials Station at Brogdale, near Faversham.

Routine spray programme.

In view of the availability of well-tried alternative insecticides it was decided to limit somewhat the amount of winter washing in the winter of 1951/52. No tar oil was applied to cherries or black currants, as aphids and caterpillar can easily be controlled with spring washes ; in the event, however, it was not found necessary to apply the latter. All peaches, loganberries, and raspberries were sprayed with 5 per cent tar oil before Christmas and all apples, pears, and plums with DNC in late February and early March, when the weather was dry and calm, ideal for spraying ; this was as well, as the latter half of March was not nearly so favourable. One 16-acre apple plantation (Kiln Field), was sprayed with an emulsible DNC containing 95 per cent oil and 3·3 per cent dinitro-ortho-cresol. This preparation is slightly cheaper per 100 gallons of dilute wash than the formulation previously used ; it is frost stable and free flowing, and the reduced bulk is a great advantage. Results here were fully equal to those obtained on the rest of the farm which was sprayed with a DNC wash containing 2·4 per cent dinitro-ortho-cresol and 65 per cent oil, as in the past.

Though probably now no longer necessary for Apple Blossom Weevil, capsid, and caterpillar control, DDT was added to the green cluster lime-sulphur spray to ensure that the Summer Fruit

Tortricid does not become established here. In general the scab spray programme followed very closely the recommendations of the 1949 edition of the ' Spray Calendar '. In the past two seasons most of the plantations of scab susceptible apples have been sprayed with lime-sulphur three times before blossoming to ensure continuous protection for the expanding foliage. This year, however, the blossom opened so quickly that it was only possible to get round twice. After blossoming, Cox's Orange Pippin trees were sprayed three times with dispersible sulphur, and other varieties once with lime-sulphur and twice with mercurated lead arsenate.

Toxaphene at 0·13 per cent was added to the first post-blossom scab spray to control Apple Sawfly in preference to BHC, as it is not so harmful to the predators of red spider. A special formulation of DPS, known not to cause damage, applied in conjunction with derris in the fruitlet stage scab spray, and a further application of derris combined with the codling spray, greatly reduced the damage by red spider. Although there was a slight autumn build-up in some places, this did not affect the quality of the fruit. Attacks by Codling Moth larvae, though severe, were not quite so bad as in 1951. All plantations received two lead sprays, and the packing shed, box shed, and stacks of orchard boxes were sprayed with DDT in oil during May to kill the first generation of moths immediately they emerged.

Cherries and plums received the recommended copper sprays for the control of bacteriosis. Czar plums and damsons were sprayed, in addition, with derris (at 2 lb. per 100 gallons) and spreader at the ' cot split ' stage against Plum Sawfly. Raspberries were only sprayed twice in 1952, once with a 50 per cent BHC spray (at 2 lb. per 100 gallons) against Cane Midge and once with derris at the pink fruit stage against beetle. Loganberries were sprayed three times during the summer : once with a cuprous oxide preparation before blossoming against cane spot, immediately after blossoming with colloidal copper, derris, nicotine, and spreader against cane spot, beetle, and aphids, and again two weeks later with derris and spreader against beetle. Fruiting strawberries were sprayed with parathion once six weeks before picking, and non-fruiting and runner beds with schradan twice, to control aphids and minimize the spread of virus. Fruiting beds were dusted with sulphur to keep Mildew in check, and DDT was added to the sulphur at the appropriate time for the control of Strawberry Blossom Weevil. DDT had no effect on the larger fruit-eating beetles.

Arable crops.

The area under arable crops increased slightly during 1952, to a total of 126 acres. The late snow and frost delayed planting almost as much as in the previous year, and the dry spell in the early summer did not encourage growth ; however, most crops yielded satisfactorily.

Potatoes.—16¼ acres of potatoes were grown, 9 acres of Stormont Dawn and 7¼ acres of Record. One field of Stormont Dawn cropped heavily for the season, yielding 48 tons from 3¾ acres. Although the same Northern Irish certified seed was used, the other 5¼ acre field suffered from a severe attack of Leaf Drop Streak, which not only reduced the yield, but, worse still, affected the cooking quality of the tubers, so that some of them had to be sold for stockfeed. Record, a heavy yielding yellow fleshed potato, was grown on contract for chipping ; the crop has not yet been delivered.

Peas.—The dry spell came at the worst time for peas and considerably reduced the yield. The 12½ acres of Surprise, on some of the more sandy soil adjacent to Larkfield Plantation, looked promising in the early stages, but there was not sufficient moisture to mature a full crop and the yield was barely 1 ton of shelled peas per acre. The 8½ acres of Lincoln also yielded poorly.

Cereals.—22¾ acres of wheat, 30¼ acres of barley and 3 acres of oats were grown. The wheat consisted of 6 acres of Eclipse, 5 acres of Squarehead 13/4, 7¾ acres of Holdfast, and 4 acres of Alte which was grown on land cleared too late for autumn planting. So far only the Squarehead and part of the Holdfast, which were threshed at harvest time, have been sold, but all the wheat looked well. The Eclipse, a fairly recent introduction, has good length straw and red grain and is supposed to stand better and to yield more heavily than Squarehead ; it certainly showed no signs of lodging, and looked promising. The barley, Plumage Archer, sown in December, was well established before the dry spell. Almost the whole crop was combine harvested and averaged 5 qr. per acre. 25½ acres of one-year ley were grown ; 7 were made into silage and 18½ into hay, most of which was secured in good condition. No second cuts were taken, the 7 acres of silage ground being bastard fallowed and the hay aftermath ploughed in to help increase soil fertility. Thirty-three Devon steers were kept through the winter to tread the cereal straw into dung. F.H.V.

Experimental nurseries.

The demand for fruit plants for experimental use continues as large as ever and, in addition, the distribution of the new range of Malling-Merton rootstocks has meant a considerable extra load on the nurseries. Four of the new series of Woolly Aphid Resistant rootstocks and one that has proved to be

not so resistant (see pages 55, 64, and 169) were grown in bulk and a total of 83,000 are being sent out to large-scaler aisers, who are prepared to use them for further propagation for the next three years. These rootstocks have been selected, amongst many other things, for good production and nursery qualities but, even so, we were surprised at the large number of first grade stocks carried per foot of row on some of them. A limited number of trees and graftwood of the new apple variety Michaelmas Red (see Annual Report for 1951, page 100) were distributed to members.

Although the wet spell in the spring delayed operations somewhat, the weather later was good for nursery work and all the nursery material grew well, though black currant cuttings, planted in the spring, suffered from the dry May. Altogether, there were in the nursery during 1952, 9,000 one-year-old trees, 2,000 two-year-old, 2,000 cherry staddles, and a variety of soft fruit plants and bushes ; almost all these were for experimental use.

Allusion is made elsewhere to the extensive programme now in progress for testing rootstocks and experimental trees for virus. Much of this work has fallen on the nursery staff, and the fact that it required the placing of 18,000 buds this year gives some idea of the careful organization and team work required.

T.V.D.

Experimental glasshouses.

One of the chief difficulties has been to keep the temperature in the two new virus houses low enough during spells of warm weather in the summer.

Since the new houses were built, temperatures have been recorded in representative compartments, especially the smaller ones and those at the southern end of the houses. The temperature varies considerably, depending on the compartment, the time of day, the height above the floor, and the efficiency of the air distribution from the ventilating system. Except at the south end, the maximum temperature has been kept a few degrees above, and, in some cases, below the outside maximum. To improve conditions in the warmest compartments, adjustments were made last winter to increase the quantity of air passing and to improve its distribution. Where this was done the number of days when the temperature was above 90° F. was reduced considerably. Two small exhaust fans were fitted in another compartment and had a similar effect. In a third compartment the scrim blind was raised a few inches above the glass to see if this would help, but the effect was not so marked.

A film of water trickling over the roof resulted in a reduction of 6° F. in the temperature inside, even though the water film was sometimes incomplete due to the variable water pressure. This seemed the most promising line of approach, and it is hoped to extend this and to modify the ventilating system further during the winter of 1952/53. The scrim blinds will be gradually replaced by wood lath blinds, as the latter are much more effective.

In the autumn of 1950 and the following summer, some fruit trees in pots under glass showed varying leaf scorches and discolorations. During 1952 cultural trials on several varieties of apple were done using blood and magnesium sulphate, the latter being applied as a spray. A distinct improvement in the leaf colour and growth has resulted, although both varied according to the variety.

In order to provide a constant supply of young leaves and shoots for laboratory work at times when these are not available under natural conditions, several different ways of growing apple seedlings during the winter months are being tried. During the winter of 1951-52 two small batches of one-year-old Worcester Pearmain seedlings, growing under varying artificial illumination in a heated glasshouse, were used for this purpose.

Seven ways of germinating apple seed have been tried ; of these, sowing after a period of about 70 days at a temperature in the region of 38° to 40° F. has proved most successful. Removal of the testa and endosperm tissue layer gave good results, but was rather laborious.

The number of plants under glass and outside continues to increase, and additional plunging space must now be found.

M.M.M.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

Notable events in a busy year have included the naming and introduction of sixteen new apple rootstocks, and the presentation of five papers to the Thirteenth International Horticultural Congress (E367 to 371).

Tree fruits.

The field trials of tree fruits, covering 105 acres, have been continued. Space only permits mention of a selection of items of special interest.

Rootstocks.

The Woolly Aphid resistant rootstocks have now been named the Malling-Merton series, since they were bred jointly by the staffs of the John Innes Horticultural Institution and East Malling Research Station. These rootstocks have been re-tested for resistance to Woolly Aphid in the last three seasons, and fifteen of them, numbered MM.101 to 115, have been distributed to research stations in the Commonwealth and U.S.A. for further trials. Four of these rootstocks, MM.104, MM.106, MM.109, and MM.111, whose nursery and field performance suggests that they may be valuable for use in Great Britain, are being distributed to nurserymen this winter as stoolbed foundation stock. One other rootstock, which cannot be regarded as highly resistant to Woolly Aphid, is being sent out as an addition to the original Malling series as M.XXV ; this rootstock is outstanding in precocity for a very vigorous rootstock (see page 169).

A paper (E371) was presented to the Thirteenth International Horticultural Congress introducing the Malling-Merton rootstocks and describing their behaviour in field trials. Supplementary trials of these rootstocks, together with trees on the Malling series, are being planted on N.A.A.S. Experimental Horticulture Stations, and sets of trees are being placed on growers' farms in widely differing districts.

Fully illustrated descriptions of the new Malling-Merton apple rootstocks with a key for their identification have been prepared for publication (see page 55), and similar work is in progress with the ' M.IX Crosses '.

A sweet cherry rootstock (*P. avium*), which appears to be somewhat dwarfing, has been propagated for field trial.

In the trial of fan peaches on four rootstocks in Bradbourne Gardens, trees on Brompton are much larger than the others and yield has varied with tree size.

Incompatibility.

Rootstock/scion compatibility tests have been maintained and extended. Scions of Oullins Golden Gage, collected from various sources, have been budded to vegetatively propagated Myrobalan rootstocks from Belgium and the U.S.A. A series of Williams' Bon Chrétien pears from France and two English sources has been worked on a range of quinces from Provence and elsewhere ; these unions will be tested after a further year's growth. Two mahaleb cherries from New Zealand are being multiplied for compatibility tests with sweet cherry scions.

Trees have been planted for a study of the effects of compatible and incompatible pear scions on the phloem structure of quince rootstocks, and to investigate to what extent similar effects can be produced by inserting chip-buds of the same varieties, or by other treatments.

A paper describing the various abnormalities found in the anatomical structure of the rootstock in Victoria/President/Myrobalan B plum trees is in the press.

Single-worked trees of the plum rootstocks Myrobalan B, Brompton, and Common Plum, grafted together in all combinations, have been planted for a study of the structure of unions between plants of the same clone, of those between different clones of the same species, and between different species.

Histological investigations.

A paper has been published (E359) on the bark percentage of apple stems and its relationship to the underlying rootstock. Arising from this, a study is being made of the anatomical structure of the phloem in such stems. In another paper (E360) it is shown that roots of a vigorous rootstock have a higher proportion of living tissue when the rootstock has been worked with a scion of a very dwarfing type than with one of a vigorous type. Trees have now been planted for further trials of scion/rootstock effects on stem and root structure.

With the object of testing whether there is a marked scion effect on the root structure of very young apple seedlings, four-month-old seedlings, propagated vegetatively in a greenhouse, have been grafted with dwarf and vigorous rootstock varieties during their first year of growth.

Unworked rootstocks of Crab C and M.VII have been planted for a study of the effect of various stem pruning practices on root structure.

Apple and plum trees have been planted for further studies on the relationship between the type and distribution of fibres, and mechanical strength. A preliminary examination has been made of the wood structure of the Malling-Merton apple rootstocks. Studies on the stem and root structure of plum rootstocks have been continued and the results are being examined in relation to the range of structure occurring in the genus *Prunus* as a whole. In the course of this work, damage caused by a dipterous cambium miner has been observed for the first time in plum trees. The development of the pith ray flecks caused by the miner has been examined microscopically. A paper entitled 'Anatomical structure in relation to rootstock behaviour' (E370) was presented to the Thirteenth International Horticultural Congress.

Propagation.

Vegetative propagation experiments have been continued jointly with the Physiology Section.

Observations on the propagation qualities of an extensive collection of apple, plum, and cherry rootstocks continue. A cherry, rooted from hardwood cuttings, has been received from New Zealand for identification and trial.

Propagation of apple by leaf-bud cuttings has been carried a stage forward; different Malling rootstocks have reacted very differently to this method of propagation and the source of the material appears to be of some importance. Some pear, plum, and cherry rootstocks have also responded to the leaf-bud method.

Batches of maiden apple trees, raised by various methods of seedling-stage grafting, have been planted for observation. Small-scale trials of early seedling-stage grafting in the open nursery have shown promise.

Double-working.

Preliminary field and nursery trials of double-working and stem-building in cherries indicate that these techniques may prove useful for this fruit, as well as for pear.

New plantations.

Useful preliminary data have been obtained from the trial of deblossoming, irrigation, and dung mulching on apple trees on Larkfield plantation, whose previous growth had been poor.

Soil management.

In the short-term ley experiment on trees of several apple varieties on M.IX, the grass was disced in in April and observations have been made on the residual effect of the ley in comparison with cultivation, both with and without applied nitrogen. In this trial, as in several others, the Biochemistry Section has determined the mineral composition of leaf samples.

The two soil management trials on Churchfields West plantation, which include comparisons of trees in various swards, clean cultivation, and straw mulch, have shown interesting differences in this their second season. Earlier work had suggested that this would be the season of maximum check to the trees by the grass, and Laxton's Superb on M.II showed clear evidence of such competition. This effect was no doubt accentuated by the dry weather experienced during April, May, June, and July (see page 80). Soil moisture studies (see below) are proving very useful in the interpretation of this trial. The Laxton's Fortune trees on M.II, grown in six different swards, showed that the perennial ryegrass-wild white clover mixture competed with the tree more severely than any of the other swards.

It is, however, of course too early to draw conclusions regarding the relative practical value of these treatments.

A paper on orchard soil management (E369) was presented to the Thirteenth International Horticultural Congress.

Inorganic fertilizers.

The factorial NPK trial is now due for further thinning which will leave only one experimental tree, Cox's Orange Pippin on M.XII, in each of the 64 plots. It is planned to sample all plots for soil analysis at this stage.

Weedkillers.

The investigation on the use of weedkillers in an apple plantation, which is to continue for five years, has now completed its third season. (See also under strawberries.)

Soil studies.

Soil studies, in connection with the soil management trials mentioned above, have included determinations of organic carbon, nitrate nitrogen, and to some extent total nitrogen and soil pH. The N.A.A.S. have generously assisted in the analyses for P_2O_5, K_2O, MgO, and in pH determinations. Work on soil structure is also continuing.

Special attention has been given to soil moisture relationships. Large differences in soil moisture have been found under different soil management practices. The use of soil moisture deficit estimates, calculated by the method of Penman, is providing data which may lead to a better understanding of the application of the Penman equation to orchard conditions, and give closer knowledge of the irrigation requirements of fruit trees (see also page 171).

A small-scale trial has been started to determine the effects of a soil conditioner on soil moisture conditions in fallow ground. Tensiometers have shown differences in soil moisture under the various treatments.

Restoration of soil uniformity.

The second phase of this trial, described in earlier Reports, was completed by the ploughing in of the ley. It is now intended to plant one half of the trial with indicator trees, while an arable rotation will be maintained on the other half.

Root studies.

Three sixteen-year-old Cox's Orange Pippin trees, on rootstocks M.I, M.II, and M.IX respectively, growing on brickearth over chalk, were excavated (see also page 45). Interesting data were obtained, particularly on root competition and root depth. A paper entitled ' Fruit plant roots and their environment ' (E368) was presented to the Thirteenth International Horticultural Congress.

Some trees adjoining the long-term cover crop trial at Larkfield have been put under grass sward, straw mulch, and cultivation, to provide material for studies of root distribution in five or ten years' time.

Pruning.

Experiments on the widening of crotch angles in plum trees by the use of growth substances are continuing in collaboration with the Physiology Section. A simpler method of applying the growth substance to the cut, as a smear in lanolin, has been developed.

In the four-year-old plum pruning trial, differences in tree shape and branch angles are now showing, the unpruned trees having very few narrow crotch angles.

A paper (E356) on pruning maiden apple trees was published.

In the peach pruning trial, differences in cropping between the two pruning systems and between varieties were marked.

Biennial bearing.

Routine records have been maintained on the young trees planted for biennial bearing studies. Experiments on older trees have been concluded and the work is being written up. The experiment on the control of biennial bearing in mature Bramley's Seedling apple by the application of defoliating sprays in the off year (1950) has proved successful. In treated trees the biennial rhythm has been broken and a good crop was harvested in 1952. The combined yield of the 1951 and 1952 crops was greater from the treated trees than from the controls. While the details of most suitable defoliant and concentration yet remain to be worked out, this method appears promising, not only for breaking an established biennial rhythm, but also for preventing its onset after a severe frost.

Blossom thinning.

Three preliminary trials of blossom thinning by spraying were carried out in Kent, Sussex, and Essex in collaboration with the N.A.A.S. and growers, and with the timely help of the Physiology Section. Trees of Miller's Seedling and Laxton's Superb were sprayed with sodium salt of DNC at 0·5 per cent at full bloom and with NAA at 40 p.p.m. 14 days after petal fall. The former proved much too drastic, and the latter failed to thin the fruitlets, indicating that the concentration was probably too strong in both cases.

Frost damage investigations.

A special fruit plot has been planted for frost studies on 2½ acres of the lowest lying land on the Station. The top fruits include 32 varieties of apple, 8 of pear, 8 of plum, and 8 of cherry, whilst the soft fruits include 11 varieties of black currant, 6 of gooseberry, 6 of raspberry, and 11 of strawberry.

The varieties chosen include the following classes : (*a*) important commercial varieties ; (*b*) varieties which may be of interest for future planting, such as Laxton's Fortune, Sunset, and Tydeman's Late Orange ; (*c*) varieties claimed to be relatively frost resistant, such as Frogmore cherry, Slavianka apple, and two strawberry seedlings from the U.S.A. ; (*d*) varieties which tend to set parthenocarpic fruits, such as Howgate Wonder and Schone von Herrnhut apple and Conference pear ; (*e*) late blossoming varieties, such as the apples Crawley Beauty and Edward VII ; (*f*) varieties which are particularly susceptible to frost damage, such as Bramley's Seedling and Belle de Boskoop. Observations will be made on the incidence of frost damage, on the ability to set fruit and carry a crop following natural frosts, and on other features in relation to frost damage.

An area of 0·6 acres of apples has also been included for tests of possible palliative or remedial measures.

A general review of frost damage and possible control measures (E367), presented to the Thirteenth International Horticultural Congress in September, 1952, included recommendations on the use of the water sprinkling method, with data on the degree of protection expected from various rates of precipitation. It is provisionally concluded that small rotary sprinklers, giving a precipitation of 3 mm./hr., would protect from radiation frosts in which the screen temperature is 24·5° F. (−4·2° C.) ; oscillating spray lines, giving 4 mm./hr., from 23·5° F. (−4·8° C.) ; and rotary rainers, giving 5 mm./hr., from 22·8° F. (−5·3° C.).

During winter frosts an array of small rotary sprinklers, covering about one-third acre, was tested in an orchard of mature apple trees. Records of water distribution, air and bud temperatures, and wind speed and direction were taken. The ice load caused by 10 hours' sprinkling during frost did not damage the trees.

During the blossom period a similar array of small sprinklers was set up, but as no critical air frost occurred the essential field tests still remain to be made.

'Washing-off' the hoar frost in the morning has been investigated under both laboratory and field conditions, using tomato, potato, and strawberry plants in pots, and strawberries growing in the field. The results have shown that 'washing off' protects plants only under special and unusual conditions (see page 73).

Varietal resistance studies were continued. In two slight frosts in April, some interesting data on early damage were obtained. Laboratory studies of varietal resistance were centred on the five apple varieties, Bramley's Seedling, Ribston Pippin, Cox's Orange Pippin, Ellison's Orange, and Worcester Pearmain. The freezing tests were supplemented with measurements of the growth rate, auxin content (carried out by the Physiology Section), water content, and the rate of loss of water during desiccation. Material was also collected for histological investigations into the nature of frost damage.

In the tests of possible delaying of blossoming, apple trees sprayed with maleic hydrazide in 1951 to delay blossoming in 1952 showed no difference from the controls in their time of flowering. A further test has been made this year, using modified treatments. Tests were also made with raspberries. Two concentrations of maleic hydrazide, each at two different levels of pH, were applied at various stages of raceme development.

A series of experiments was carried out to investigate the effect of a number of known growth inhibitors upon the frost susceptibility of certain fruit trees. Ten such inhibitors were tested. In addition, four other substances were used, including apple juice. This last was tried as being a possible source of blastocollin and chlorogenic acid (see page 31).

The process of freezing in plant cells has been studied under the microscope using a special slide fitted with a thermocouple and cooled by dry ice. The staminal hairs of *Tradescantia* sp. and the epidermis of ripe cherries were used as suitable material. A short film on this subject was shown at the Thirteenth International Horticultural Congress.

Breeding.

A description of the new apple variety, Michaelmas Red (derived from a cross between McIntosh Red and Worcester Pearmain) has been published (E365), and scion material is now available.

Preparations have been continued for breeding new late flowering apple varieties of high fruit quality. The breeding and testing of apple seedlings for resistance to Woolly Aphid has been continued.

A further season's work has confirmed that there is a small significant difference, in fruit size and weight, between Cox's Orange Pippin apples pollinated by King of the Pippins and by Worcester Pearmain. Results obtained in 1950 and 1951 have been published (E357 and 358).

Small fruits.

The area of small fruit trials, 8·4 acres, is lower than for some years.

Variety and strain trials.

Strawberries.—In strain and variety trials Climax has again given the highest yield of marketable fruit, while Early Cambridge cropped heavily and over a long season. A number of Cambridge seedlings, including Cambridge Profusion (257), Cambridge Premier (276), and Cambridge Regent (679), have cropped as maidens for the first time in a replicated trial. See also page 176.

Raspberries.—The two cropping trials, which bore their 6th and 4th crops respectively, did exceptionally well. In both trials the average crop of all varieties was well over 4 tons per acre, the heaviest average ever recorded at East Malling.

Of the 12 varieties in the older trial, Malling Promise came first and Malling Exploit second.

Of the 8 varieties in the younger trial, Seedling 51/47 came first, for the third time in four years, with nearly 106 cwt. per acre. Here Malling Promise was second and Seedling T third (Malling Exploit is not in this trial). Norfolk Giant was seventh with 72 cwt. per acre. In average crop for four years 51/47 is well ahead with 71 cwt. per acre per year, followed by Malling Promise with 62 cwt.

In the small trial of the New Zealand and Amos stocks of Lloyd George, with Malling Promise and Malling Exploit for comparison, the New Zealand stock again led at 94 cwt. per acre ; the other three were close together, with from 83 to 84½ cwt. per acre. A paper on raspberry varieties (E361) was published.

Loganberries.—In a trial of Malling clonal Loganberry and thornless Loganberry, the Malling clone has borne a much heavier crop than the thornless variety.

Black currants.—The variety trials of black currants have been concluded and reports are being prepared.

Propagation.

Trials are in progress with black currants, comparing stools and bushes as sources of cuttings, and with gooseberries, testing the source of cutting and treatment with growth substances, in four planting situations.

Breeding.

Raspberries.—Seeds of one further family of red raspberry, a cross of the two most promising self-pollinated seedlings so far produced at East Malling, germinated in 1952. Small families of Boysenberry × Malling Exploit and of Boysenberry selfed for comparison also germinated.

The seedlings of thirteen raspberry families germinated in 1950 cropped fairly well ; several individuals have been selected for further breeding.

Black currants.—Promising selections from first crosses between the main commercial varieties are being kept under observation. Several hybrids between the black currant and related species of *Ribes* were raised and both seeds and seedlings were subjected to colchicine treatment to induce chromosome doubling. A number of colchicine induced tetraploids of black currant variety selfs and crosses are being kept under observation.

Cultural measures.

Strawberries. -The spacing trial of Climax, comparing matted and spaced planting systems, gave an average yield of about 3½ tons to the acre, the wide matted beds showing again that root competition severely limits the crop in a season of drought. A trial of Royal Sovereign, comparing modified matted rows and beds, has cropped for the first time.

Weedkiller trials have been continued, but without very promising results so far.

In a trial of burning-over after cropping, the burnt plots again bore a heavier subsequent crop than those not burnt. Data from several such trials are being prepared for publication.

Raspberries.—The trial comparing straw mulch with cultivation at two levels of nitrogen has again given promising results in favour of straw mulch.

Black currants.—The mulching and pruning trials have been concluded. Papers are in preparation.

Mycorrhiza.

Experiments designed to show whether the fungal fructifications found associated with mycorrhizal strawberry roots, in 1951 and subsequently, belong to the endotrophic mycorrhiza fungus have given promising results. A technique has been developed in collaboration with the Pathology Section for sterilizing the fructifications and spores, and for growing strawberry seedlings aseptically in test-tubes (see page 34). Some typical mycorrhizal infections have been obtained in strawberry seedlings growing in test-tubes in soil sterilized by autoclaving and with propylene dioxide, and inoculated with the fruit bodies and sterilized spores excised from these. Attempts have also been made to germinate the fungus spores on culture media. An account of this work will shortly be published.

Walnuts.

Many trees again carried good crops, particularly the variety Sutton Seedling. The quality on the whole was good.

Horticultural meteorology.

Routine meteorological observations and special records of air temperature, soil moisture, and wind in relation to various experiments have been maintained.

Observations at the sub-station at Throwley have been maintained. The Meteorological Office has again kindly provided special frost warnings for the frost investigations.

A study of wind records during the blossom season in some Kent orchards was published (E362).

Publications During the Year.

Tubbs, F. R. **East Malling Research Station.** Proc. roy. Soc., 1951, **139,** 1-18 (E355).

Preston, A. P. **Pruning maiden apple trees as bushes.** Rep. E. Malling Res. Sta. for 1951 (1952), 199 (E356).

Tydeman, H. M. **The influence of the pollen parent on the development of apple fruits.** Rep. E. Malling Res. Sta. for 1951 (1952), 62-6 (E357).

——— **The effect of the time of pollination on fruit development and maturity in Cox's Orange Pippin apples.** Rep. E. Malling Res. Sta. for 1951 (1952), 67-9 (E358).

Mosse, B. **A study of the bark-wood relationship in apple stems.** Rep. E. Malling Res. Sta. for 1951 (1952), 70-5 (E359).

Thompson, E. C. **Anatomical studies of stems and roots of hardy fruit trees. V. The histology of the roots of the apple Malling Crab C when budded with certain scion and rootstock varieties.** Rep. E. Malling Res. Sta. for 1951 (1952), 76-81 (E360).

Wood, C. A. **Raspberry varieties in Great Britain.** Rep. E. Malling Res. Sta. for 1951 (1952), 82-92 (E361).

Preston, A. P. **Wind records in some Kent orchards.** Rep. E. Malling Res. Sta. for 1951 (1952), 93-6 (E362).

——— **Weather conditions during 1951.** Rep. E. Malling Res. Sta. for 1951 (1952), 97-9 (E363).

Villiers, F. H. **The experimental farm.** Rep. E. Malling Res. Sta. for 1951 (1952), 17-23 (E364).

Tydeman, H. M. **Michaelmas Red—a new dessert apple.** Rep. E. Malling Res. Sta. for 1951 (1952), 100 (E365).

Rogers, W. S. **Some aspects of spring frost damage to fruit and its control.** 13th int. hort. Congr., London, 1952 (in the press) (E367).

——— **Fruit plant roots and their environment.** 13th int. hort. Congr., London, 1952 (in the press) (E368).

Greenham, D. W. P. **Orchard soil management.** 13th int. hort. Congr., London, 1952 (in the press) (E369).

Beakbane, A. B. **Anatomical structure in relation to rootstock behaviour.** 13th int. hort. Congr., London, 1952 (in the press) (E370).

Preston, A. P. **Some new apple rootstocks.** 13th int. hort. Congr., London, 1952 (in the press) (E371).

Beard, F. H. **Seven clonal selections of Golding hops.** Rep. E. Malling Res. Sta. for 1951 (1952), 189-96 (B71).

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

Routine work.

During the year there has been so large an increase in the amount of routine analytic work that the general restriction of other activities, referred to last year, has necessarily continued. In particular, the total number of statistical analyses rose from 267 to 633. The increase has come principally from within the Research Station, the amount of work done for the N.A.A.S. being at about the level anticipated. A further increase in the Section's commitments must be reported. Proposals by N.A.A.S. officers for fruit experiments outside the Experimental Horticulture Stations, sponsored by Provincial Experiments Committees, will in future first be discussed with the Scientific Liaison Section. If approved, the Statistics Section will be responsible for the statistical aspects of the trials. Statistical help to other bodies has continued, notably to the Scottish Horticultural Research Institute, the Essex Farm Institute, Writtle, and to experimenters in Southern Rhodesia, Cyprus, and the Kingdom of Jordan.

East Malling.

Less time has been available than usual for librarian duties in the Records Office, but, with the help of other interested members of staff, routine summaries have nearly been kept up to date. The making of plans also has been restricted, but the number of statistical analyses has increased enormously —from 253 to 604. Of these, 452 (as against 141) have been on behalf of the Pomology Section, the increase being partly occasioned by the Horticultural Congress in London, but more by the coming into bearing of a large number of trees planted in 1945 and after. The commonest technique was that of the analysis of variance (486), but the analysis of covariance also was largely used (56). Many fresh trials have been designed and, in others that have fulfilled their original purpose, new treatments have been superimposed by the use of methods recently evolved.

N.A.A.S. Experimental Horticulture Stations.

The four Stations at Luddington, Warwickshire; Efford, Hampshire; Stockbridge House, Yorkshire; and Fairfield, Lancashire, have each been visited more than once during the year for the purpose of locating the various trials in their experimental programmes, so that suitable designs could be prepared. In addition, the new Station at Rosewarne, Cornwall, and its Sub-station at Ellbridge, were visited to assess their potentialities for fruit experiments. A large number of experimental designs for these Stations has been made, making use of recent developments at East Malling, notably designs to dispense with outside guard rows. At Luddington, the first crop from a strawberry spraying trial was recorded, but results have not yet been received for analysis.

N.A.A.S. Provincial experiments.

Up to the present this new activity has not occasioned a lot of work, though some trials have been designed. Ten statistical analyses were carried out, as compared with six in 1951, before any special responsibility had been assumed.

Statistical research.

Methods of experimental design and interpretation.

Further work has been done on designs that will permit the addition of a new set of treatments to an existing trial, or permit the omission of external guards. In this connection, new methods of partially balancing treatments have been explored and have led to the evolution of designs, some of them of high efficiency. The possibility of bias in the significance tests appropriate to these designs is being studied in general terms, but preliminary work on particular designs has not shown any to be invalid on this account. A report has been published (M19) on designs of this sort derivable from Latin squares.

A further report (M18) describing the design of calibration trials for three varieties was published in last year's Annual Report. No further developments in this kind of work are contemplated at present.

The preparation for publication of a general review of statistical methods for experimentation with fruit trees has led to a reconsideration of methods currently used at East Malling. In particular,

studies have been made of (1) the problems arising from the analysis of a single trial where there is no possibility of confirming doubtful results, (2) the interpretation of particular treatment differences when a comprehensive test has shown that there are significant differences between the treatments, and (3) the modifications called for in the analysis of variance when there is a systematic element in the design. In addition to these studies, formulae have been evolved (4) for the accuracy of treatment comparisons in Latin squares when some data are missing, and (5) for grouping a range of varieties in respect of some important characteristic, e.g. rootstocks in order of vigour, if they are too diverse to be compared together in a single trial.

A study has also been made of the consequences of applying each treatment to part of a tree, where there may be indirect effects on other parts receiving different treatments.

Advances have been made in the interpretation of certain types of laboratory trials, especially by use of probit analysis and allied techniques.

Biometrics (plant variation and sampling).

The attempt to put the assessment of tree-to-tree variation on a sounder mathematical basis has been successfully concluded in an unexpectedly short space of time. It has led to useful results and the work is temporarily in abeyance. No further work has been done on the accuracy of split-plot designs.

Further work has been done on the use of combined measures of height and spread of strawberry plants, latterly with disappointing results, correlations of crop with previous size measurements being in general too low to be of value.

Studies in the use of eye estimates for the weight of crops of individual trees have continued. Such a method would be useful for experiments on growers' plantations, where actual weights cannot be obtained. It is too early to make any recommendation, but results are promising.

The study on the estimation of tree weight is continuing. Measures of extension growth are now being considered as a supplement to trunk girths in this estimation.

An attempt was made to estimate total strawberry crops from some of the pickings only, but without success.

Field trials.

Both the apple uniformity trial, and the experiment on the restoration of uniformity of land being carried out in collaboration with the Pomology Section, have continued.

Publications During the Year.

Pearce, S. C. **Studies in the measurement of apple trees. I. The use of trunk girths to estimate tree size.** Rep. E. Malling Res. Sta. for 1951 (1952), 101-4 (M17).

——— **The design of calibration trials with three varieties.** Rep. E. Malling Res. Sta. for 1951 (1952), 105-7 (M18).

——— **Some new designs of Latin square type.** J. R. statist. Soc., Ser. B, 1952, **14**, 101-6 (M19).

III. PLANT PHYSIOLOGY

By M. C. VYVYAN

Close collaboration between the Plant Physiology Section and the staff of the Research Institute of Plant Physiology under Professor F. G. Gregory has continued, and the following report includes reference to the work of the latter carried out at East Malling.

Physiology of growth and form in fruit trees.

The stock on stock trees have completed their second year's growth since budding, without any ill-effects from the dry summer. Routine sprays of lime-sulphur plus DDT controlled the troubles experienced last year. Samples were taken in March, May, July, and September, and the detailed growth records continued on the two ' typical trees ' in each of the 120 plots. In order to analyse tree growth in terms of leaf area as well as weight, large numbers of area determinations are required ; for this purpose an instrument was made to measure the areas of leaf samples up to 400 sq. cm. at a time. Handling the voluminous data from this experiment has been facilitated by transcribing it on to punched cards, so that classification according to stock, scion, position, or time can be carried out rapidly. Meanwhile, analysis of the earlier experiments on stock-scion relationships, interrupted by the war and by work on fruit-drop control, has now reached a stage at which publication of results can be undertaken.

The technique for growing trees in a nutrient mist, alluded to last year, has been employed this year on a ' pilot plant ' scale (see page 95).

An experiment was conducted on four-year-old Cox and Worcester trees to determine the effect of light and severe pruning at four dates (November, 1951, February, April, and June, 1952) on the subsequent growth made by the trees, as shown by a series of measurements of total extension growth, and diameter of leader shoots.

An investigation of the factors controlling internode growth has been taken up by a postgraduate worker. The very young leaves in the terminal bud have been found to exert a profound effect on the extension of internodes of both apple and tomato stems.

Further work on crotch angle control, both on Victoria plum trees in collaboration with the Pomology Section, and on an intensive scale on Myrobalan B layer-bed shoots, was a failure this year owing to the drought early in the summer, which severely restricted branch growth and lateral bud break respectively.

Hormone relations in fruit trees.

Using the coleoptile curvature technique the nett growth-promoting or growth-inhibiting activities of simple ether extracts of stem tissues were assayed. Vegetative shoots of some apple and plum rootstocks were surveyed throughout growth and dormancy, and, in Crab C in particular, observations were also made on bud material. It was found that differences early in the season in transportable auxin were reflected later in the content of storage auxin in dormant shoots.

Further studies were made this year on auxin transport in stems with emphasis on the role of the tip and the young leaves. The ' tip ', i.e. the stem apex and all unexpanded leaves, was found to be the main source of auxin, while the first four expanded leaves contributed little. This may well be linked with the control of internode growth by the tip.

In an attempt to separate the growth-promoting from the inhibiting substances extracted from plant material with ether, paper chromatography has been employed. Because the *Avena* coleoptile curvature test was not altogether satisfactory for assaying the substances on these chromatograms, another test method has been used, which is a modification of the *Avena* coleoptile straight growth test (see page 88).

For certain purposes an even more sensitive biological assay method for growth substances would be useful, and to this end work has been done on the ' cress root test '. Growth of these seedling roots is inhibited by higher concentrations of indole-acetic acid, but stimulated considerably at very low concentrations of the order of 10^{-5} p.p.m. This test, however, is not yet standardized for use as an assay method.

Vegetative propagation.

Investigations into the rooting and growth of cuttings have once more been conducted jointly with the Pomology Section. There has also been wider collaboration with the N.A.A.S. in experiments on gooseberry and black currant cuttings, and with the Nursery Research Station at Boskoop, Holland, in experiments on the effects on rooting and growth of source of material, environmental factors, and storage of cuttings before planting.

Other studies concerned the influence of the time of taking cuttings on rooting, using standard and heavy indole-butyric acid dip treatments, and the effects on rooting of different water tables. Source studies were also extended to root cuttings and leaf-bud cuttings of apples.

In the stoolbeds used by the Physiology Section as a source of shoots for experimental purposes, a leaf discoloration has been noticed for some time on Crab C and M.IX. An experiment carried out in collaboration with the Biochemistry Section has shown that magnesium sulphate sprays considerably reduced the leaf symptoms, potassium sulphate having no effect.

Abscission, including fruit thinning.

Two experiments were carried out on thinning apples by NAA sprays, one on Early Victoria and the other on Sunset. No advantageous effects were obtained, 5 p.p.m. NAA being too low a concentration to have any result, while 40 p.p.m. was too high, causing foliar damage and reduction in final fruit size. It is clear that caution is needed in this country in using this method of thinning fruits, although elsewhere it has proved useful.

Five intensive experiments were carried out on particular problems of abscission. The most elaborate involved 56 treatments, replicated eight times, and was concerned with determining the critical period in the abscission process during which inhibition can be brought about by NAA. Three others dealt with the different responses of pedicels and petioles to NAA, the response of petioles of four apple and two plum rootstocks to NAA, and the effect on the abscission of Crab C petioles of sprays of potassium and magnesium. The final experiment confirmed, with the synthetic substance, the results obtained last year with a plant extract tested for abscission-inhibiting powers for the Botany Department, Manchester University. Since the former test the Manchester workers had identified the substance in the extract as indoleacetonitrile ; it is much less effective on apple petioles than IAA or NAA.

Spray damage.

This work has continued as a joint investigation with the Plant Protective Chemistry Section, and this year has been on three main aspects : firstly, study on the efficiency of wetters, with particular reference to the penetration of the hair mat on leaves by drops of solutions, and the errors inherent in the estimation methods used ; secondly, a study of the effect of wetters on the damage caused by various poisons when applied in high-volume sprays. It was found that the damage caused depended on the nature of the poison and the wetter used rather than simply upon the efficiency of the wetting achieved ; thirdly, preliminary work was begun on damage caused by low-volume spraying, experiments being carried out to determine the relation between dose of copper sulphate in milligrams per sq. cm. of leaf, concentration of spray applied, and resultant damage.

Publications During the Year.

Vyvyan, M. C. and Trowell, G. F. **Use of sprays to control fruit drop. VIII. Further trials with NAA sprays on the apple variety Bramley's Seedling.** Rep. E. Malling Res. Sta. for 1951 (1952), 108-11 (F65).

——— ——— **Use of sprays to control fruit drop. IX. Further trials of the effects of delay in picking and of NAA sprays on fruit drop in Cox's Orange Pippin.** Rep. E. Malling Res. Sta. for 1951 (1952), 112-14 (F66).

Llewelyn, F. W. M. and Allen, M. **A method of estimating scorch on leaves.** Rep. E. Malling Res. Sta. for 1951 (1952), 115-18 (F67).

——— ——— **The effect of wetter concentration on ammonium thiocyanate damage to raspberry leaves, and on the volume of spray required to achieve complete wetting.** Rep. E. Malling Res. Sta. for 1951 (1952), 119-21 (F68).

Barlow, H. W. B. **The importance of abscission in fruit production.** 13th int. hort. Congr., London, 1952 (in the press) (F69).

IV. BIOCHEMISTRY

By W. A. ROACH

A preliminary survey has been made of the variability in mineral composition of different parts of the apple tree, both when grown under controlled mineral nutrition and in the plantation, while promising advances have been made in the study of the organic constituents of fruit plants.

Quantitative methods, applicable to a single apple leaf, have been evolved for the estimation of the sugars : glucose, fructose, sucrose, raffinose, and stachyose, together with the sugar-alcohol sorbitol, all of which have been found in leaves of fruit plants. These may be determined singly, or as a total carbohydrate figure that has a definite chemical meaning. Progress has also been made on the difficult problem of determining the ' reserve ' carbohydrates, including starch. A potentially valuable method for the direct measurement of absorption spectra of spots, without removal from the chromatogram, has been developed and should prove of particular value in the study of the ' ethyl acetate fraction '. Chlorogenic and isochlorogenic acids in pear leaves and the related substance quinic acid have been identified in a number of apple and pear tissues.

Analytical methods.

Wiping leaves with muslin, as practised at Malling in the past, does not appear to be an efficient cleaning method. Normal leaf samples so treated lost considerable amounts of iron when washed with dilute mineral acid or detergent solution ; whereas leaves from shoots encased in plastic bags, to exclude dust, washed in the same way, lost no appreciable quantities of iron. A washing method is therefore being adopted.

In the past, deductions have been drawn from comparisons made between the analyses of spectra of leaf samples, collected as close together as possible. In this way, the error due to surface contamination would be similar. The majority of such deductions are therefore likely to be reliable. Further, many of them were supported by the results of diagnostic leaf injection.

Spectrographic methods.

Flame method.—The quantitative modification described last year (K93) has been applied to over 1,000 samples, and some 3,500 determinations of potassium, iron, manganese, and copper have been made. This work indicated that barium was a suitable internal standard for calcium, even when silicon was present, but lead was quite unsuitable for magnesium in the presence of silica. Further, for accurate estimation of magnesium above 0·3 per cent it is necessary to use a smaller sample than 50 mg. because of a reduction in the slope of the standard curve, caused by self-absorption in the cooler outer layers of the flame.

During the last three months work has been carried out with a view to establishing the final form of the method for routine quantitative work. An exhaustive survey has failed to reveal any element more suitable than lead as the internal standard for magnesium ; consequently it has become necessary to remove silica. Attempts are being made to do this by converting the silica into the fluoride. In working with elements covering a wide wavelength range, a rotating stepped sector has been found to be more reliable than a neutral stepped filter and has therefore been incorporated into the method.

Arc method.—The aim has been to evolve a method, as simple and rapid as the flame method, for the determination of the elements cobalt, nickel, molybdenum, and zinc in samples of less than one gram. Encouraging progress has been made.

Organic constituents of fruit plants.

Differences have been observed in the composition of the mixed group of compounds comprising glycosides, tannins, etc., present in leaves of different varieties of apple and pear. Differences also result from nutritional deficiencies. The difficult work of identification of these substances has been facilitated by the development of the new technique of absorption spectrophotometry on paper strip chromatograms, referred to above.

The substance responsible for a prominent spot in paper chromatograms of extracts of pear leaves and shoots has been identified as chlorogenic acid. A second prominent spot was found to give an absorption spectrum almost identical with that of chlorogenic acid.

Direct comparison of the material from pear with the recently discovered isochlorogenic acid, from green coffee beans, shows them to be very closely similar or identical. Complete proof of identity will not be possible until isochlorogenic acid or some derivative of it has been obtained crystalline.

Chlorogenic acid is a derivative of quinic acid, and it is of interest to find that the latter substance is also present in apple and pear tissues. Dr. A. C. Hulme of the Ditton Laboratory has found chlorogenic acid and quinic acid in young apple fruits. It is a pleasure to record close collaboration between the two laboratories while the identification of these substances was in progress.

Methods have been studied for the determination of the soluble carbohydrates in fruit plants, both individually and collectively as ' total carbohydrates '. For the latter purpose a satisfactory method, based on oxidation by periodate in acid solution, has been developed. It is necessary, in any quantitative study of the carbohydrate balance of the plant, to know something of the stored carbohydrate, mainly starch. Unfortunately, because of the close association between starch and other complex polysaccharides in woody tissues, no satisfactory method of determining their starch content exists, but progress is being made.

During the year, collaboration with the Pathology Section on the chemical aspects of the resistance to scab of apple and pear varieties has been maintained.

The honeydew of various species of aphides has been examined at the request of the Entomology Section.

Studies in nutrition.

Analytical determination.

About a thousand samples, generally a single leaf, taken from the 1951 spray culture experiment, were analysed spectrographically for potassium, manganese, and iron. The composition of individual leaves varied from the base of the shoot upwards. The percentage amount of dry matter of certain elements was twice as much in the base as in the tip ; and of others the reverse was true. The composition of a given leaf, or other portion of a plant, varied markedly with season and with nutrient supply. Omitting one nutrient element from the solution led to big changes in the amounts of the other elements.

Rootstock material.—Rootstock material, taken from the stool-bed, was analysed for nitrogen, potassium, phosphorus, calcium, magnesium, iron, and manganese. Again there was a marked gradient in composition of leaf from the base of the shoot upwards and marked changes as the season advanced.

Cover cropping.—Work has continued in co-operation with the Pomology Section, and interesting results are being obtained.

Biennial bearing.—A sudden change in leaf composition in respect to certain elements was found in ' off year ', but not in ' on year ', trees early in June, when fruit bud differentiation becomes apparent. Samples will be analysed to complete the two-year cycle. Material for further work has been selected both on the Station and in commercial plantations, and samples have been taken for analysis in the winter. This work has involved the analysis of about 1,000 samples spectrographically for three elements and over 500 microchemically for seven elements.

Magnesium deficiency.—The magnesium spraying experiment on Plot E35, that has shown, from time to time, the symptoms associated with magnesium deficiency, has been continued. The symptoms have been prevented by spraying four times with 2 per cent magnesium sulphate, starting on 22nd May. Effects on yield and quality of crop and on red spider infestation are being studied.

Plant injection.

Co-operation has continued with the Pomology Section to see how far the injection of individual experimental trees of poor performance with potassium phosphate and urea will bring them into sufficiently rapid growth for the experimental purposes in view. No effect was apparent following the first injection.

Diagnostic injections have been done periodically throughout the season on trees on the C2 apple manurial trial affected by a shoot die-back. There were strong colour responses to copper and zinc early in the season but none later. These results will be followed up.

Tests were also made in a plantation of raspberries seriously affected by cessation of growth at the growing point. There was a spectacular increase in growth in each leaf on the side permeated by copper. This has been followed up by a spraying experiment.

Spray culture of apple rooted shoots.

Experience showed that the day-to-day running of the apparatus described in the last Annual Report showed that improvements were necessary. An apparatus is now under construction in which

the glass piston and cylinder parts of hypodermic syringes are used to deliver nutrient liquid. The growth figures for the 1951 experiment are being examined in co-operation with the Statistics and Physiology Sections.

Thus, although much remains to be done, especially on the organic side, a start has been made on a systematic study of the uptake of nutrients by the plant and their effects on the organic composition. The aim is not only to study the effects of deficiencies in themselves, but to use these as a means of studying the chains of chemical reactions going on in the normal plant.

Rooting of leaf-bud cuttings in nutrient solutions.*

Experiments have shown that it is possible to root leaf-bud cuttings of M.V apple rootstocks in warm aerated water cultures. There is no evidence of any beneficial effect of a preliminary treatment of the cuttings with solutions of sucrose, glycine, or a mixture of sucrose and glycine.

A comparison of the growth rate of leaf-bud cuttings of M.V apple rootstocks has been made in culture solutions at three levels of aeration. The growth rate, as measured by increase in fresh weight over a period of five months, did not differ significantly in the three treatments ; however, these results must be interpreted with caution as there was no replication of containers.

The effect of increased carbon dioxide in the soil on the growth of M.V apple rootstocks and of Majestic potatoes.*

Addition of carbon dioxide to the soil in pot cultures of M.V apple rootstocks has been shown to cause a reduction in the growth rate of the plants and a diminution in the iron content of the leaves. There was also a marked effect on root structure.

Addition of carbon dioxide to pot cultures of Majestic potatoes reduced total growth, and the ratio of tuber weight to that of the whole plant ; it increased the potassium concentration in the leaves and delayed senescence.

Publications During the Year.

Vanstone, F. H. **A quantitative method of flame spectrographic analysis.** Rep. E. Malling Res. Sta. for 1951 (1952), 122-5 (K93).

Mason, A. C. **A sensitive method for the determination of magnesium using Titan Yellow.** Rep. E. Malling Res. Sta. for 1951 (1952), 126-7 (K94).

Bradfield, A. E., Flood, A. E. *et alia*. **Chlorogenic acids in fruit trees.** Nature, Lond., 1952, **170**, 168-9 (K95).

Roach, W. A. **Preliminary diagnosis of mineral deficiencies by plant analysis and plant injection.** Int. Congr. Soil Sci., Dublin, 1952, 240-1 (K97).

* Work is being carried out by members of the Staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology, working in collaboration with the Biochemistry Section.

V. PLANT PATHOLOGY

By R. V. HARRIS

Bacteriosis of stone fruits (*Pseudomonas mors-prunorum*).

Continuing the study of the annual disease-cycle on cherries, the importance of concentration of inoculum in determining infection through leaf scars was confirmed. In inoculation experiments much higher concentrations were necessary to establish a given level of infection in a resistant than in a susceptible variety. Time of inoculation was also found to be an important factor, and the relationship between time of inoculation and level of infection supported the conclusion from a field comparison of bactericides that the timing of the autumn spray treatment might profitably be re-examined. A field experiment on the latter was continued, and a parallel one on bacteriosis of plums was started at an Experimental Horticulture Station of the N.A.A.S.

Turning to the natural sources of inoculum at the time of leaf fall, confirmatory evidence was obtained that more concentrated inoculum is available in autumn on the leaves of a susceptible than of a resistant variety. In qualitative estimates of these leaf surface populations a saprophytic bacterium was found coexisting with the pathogen, and evidence so far suggests that this may influence the inoculum potential and thus the level of leaf scar infection. The biological characteristics of this saprophytic bacterium are being studied. Studies of the relationship between leaf spot severity and spur infection were also continued. (An account of bacteriosis of apricots caused by the same pathogen has been prepared for publication.)

Cauliflower disease and related disorders of strawberry.

Experiments this year in collaboration with the Entomology Section confirmed an association between eelworms and *Corynebacterium fascians* in the etiology of Cauliflower disease of strawberry and an account has been prepared for publication. Attempts to determine the etiology of symptoms allied to those of Cauliflower have not been uniformly successful because of the difficulty of excluding contaminant strains of *C. fascians* from test plants. Work of this nature suggests that the latter organism may be widespread, and attention is now being given to the problem of growing strawberries for inoculation experiments under completely sterile conditions.

Mycorrhiza of strawberry.

In collaboration with the Pomology Section, attempts are being made to establish in pure culture a fungus, the fructifications of which appear to be associated with endotrophic mycorrhiza of strawberry, and to determine the nature of this association by the inoculation of strawberry seedlings, raised aseptically in test-tubes, with these isolates (see page 26).

Apple and Pear Scab investigations (*Venturia* sp.).

Studies of the fundamental causes of interspecific and varietal variation in susceptibility to scab were continued along two main lines, namely, the continued collection and maintenance unimpaired of isolates from a wide range of host sources, and the determination of the action of extracts of certain normal sap constituents of apple and pear on the growth of selected isolates from this collection *in vitro* and *in vivo*.

Certain of the sap constituents derived from the phenolic fractions were found markedly to inhibit or to stimulate the pathogen *in vitro*, the precise influence varying with (*a*) the host source of the constituent, (*b*) its concentration, (*c*) the species and strain of the pathogen, and (*d*) the composition of the nutrient substrate in respect of certain elements. Thus certain phenolic sap constituents were found both to stimulate or inhibit *Venturia* under appropriately adjusted conditions. A start was made with *in vivo* tests of these host substances in the glasshouse, on uniform sets of artificially inoculated apple and pear trees.

An account of a long series of observations and experiments on the influence of manuring on the incidence of Apple Scab (and also Canker and Branch Blister) has been prepared for publication.

Hop diseases.

Verticillium Wilt.

Owing to staff changes during the year, research on the more fundamental aspects of this problem was necessarily retarded in favour of the *ad hoc* testing and development of Wilt-resistant hop varieties. For an account of the work of recent years in this field, see page 112. These varieties are conveniently grouped as follows : (*a*) the Wye varieties bred by Salmon primarily for cultural and brewing characters, found by test to be Wilt-resistant, and now in a comparatively advanced stage of testing and availability to the industry ; (*b*) East Malling seedlings of the C, D, and J series, derived from open-pollinated seedlings of the Wye series and other seedlings also found to be Wilt-resistant, and already entered, or about to enter, on large-scale (farm) resistance and cultural trials ; and (*c*) the Wye-East Malling seedlings bred specifically for resistance as a joint project with the Hop Research Department of Wye College and given their primary selection tests at East Malling this year.

Because the two most widely cultivated varieties in the first division (Keyworth's Early and Keyworth's Mid-season) have not yet found general acceptance by the Brewing Industry comparable to the Fuggle and other varieties they were developed to replace, our work this year was largely concentrated on the seedlings of the two latter groups. A very low proportion of Wilt was recorded on farm trials of the C2, D1, and D3 seedlings and full cultural records were made. We also co-operated with the New Varieties Committee of the Hops Marketing Board and with the Hops Sub-Committee of the Institute of Brewing in arrangements for large-scale brewing tests of these seedlings, utilizing for this purpose the yields from these trials.

During the year intensive propagation of a seedling of the J series (J2) was carried out. This seedling had shown moderate Wilt resistance in small-scale tests hitherto, and has the possible advantage over the C and D series of an exclusively English parentage (and aroma), being derived from a resistant variety (1147) of the Golding type, the property of Messrs. Whitbread. Sufficient material was raised to plant two farm trials next year on naturally infected soil.

In addition to the propagation of J2, basic healthy stocks of all Wilt-resistant varieties and seedlings under review were maintained.

Samples of dried hops from 8 seedlings in the C, D, and J series were supplied to the laboratories of the Brewing Industries Research Foundation at Nutfield for preliminary small-scale brewing tests.

Of the Wye-East Malling seedlings, approximately 2,000 were given their first test for Wilt-resistance and no less than 600 remained free from any signs of Wilt under the stringent conditions of this test. Of these some 400 were discarded on cultural grounds, and the balance of about 200 seedlings will enter upon the second phase of testing and selection next year.

As laboratory studies in host-pathogen relations were necessarily retarded in the circumstances described above, the series of experiments on the response of hop shoots to *Verticillium* culture filtrates, as measured by the potometer-transpirometer (C296), was not completed as planned. Substantial evidence was obtained, however, that stems of a sensitive and of a resistant variety react similarly when subjected to direct treatment with culture filtrate from a progressive strain, and that the filtrates from a fluctuating strain produce the same effects as those from a progressive strain.

Techniques were also devised for the measurement of water uptake by several detached leaves simultaneously in further studies on reaction to toxins, and for the rapid production of small rooted shoots for root infection studies.

A critical review of previous infection experiments in their bearing on the nature of varietal resistance, with an account of recent experiments with graft combinations of sensitive and resistant varieties, has been prepared for publication.

Virus diseases.

During the year experiments set up in 1951 to test the common hop aphid *Phorodon humuli* as a possible vector of Hop Mosaic yielded positive results which included both the transmission of a line-pattern mosaic, and of typical Hop Mosaic, to the sensitive Petham Golding indicator variety. A preliminary note on these results was prepared for publication. Further experiments were started on the relation between these mosaic symptom types, using both the hop and those hedgerow *Prunus* species that act as a winter host of the aphid vector. Grafting experiments were also set up to find whether a mild non-lethal form of mosaic, known as ' Cobb's Mosaic ' because of its appearance on that variety, was caused by transmissible virus distinct from that of Hop Mosaic. Results to date confirm this supposition.

Attempts to inactivate hop viruses by the heat-treatment of nodal cuts of layered bine gave positive results with Mosaic-infected Fuggle.

In an attempt to discover more efficient indicator varieties for experiments with Nettlehead and Mosaic, the promising Early Prolific hop, re-introduced from Belgium, was intensively propagated

prior to further testing experiments. Series of hop seedling plants were also tested for possible shock-reaction to the Mosaic and Nettlehead viruses.

A selection of Fuggle, rogued over a considerable period for traces of Nettlehead and Split Leaf Blotch diseases, was further rigorously selected, in conjunction with Wye College and the N.A.A.S., for future propagation in an isolated locality as a potential source of this variety for the proposed Special Stock certification purposes of the Ministry of Agriculture and Fisheries.

Virus diseases of fruit.

The year's work included many experiments on tree fruit, strawberry, and bush fruit viruses, but for reasons of space only the more outstanding lines of advance can be mentioned. That side of the investigations involving the extensive indexing of the Station's tree fruit experiments for non-expressed virus infection, and the identification, propagation, and maintenance, of virus-free sources of planting stock was only possible through the co-operation of the Pomology and other Sections and the Farm staff.

Apple.

Following the verification of different strains of Apple Mosaic (C290), investigations during the year have shown that each strain of mosaic virus has a distinct range of varietal sensitivity or tolerance, and a given apple variety cannot therefore be described as generally tolerant or sensitive to these viruses, or a mosaic virus strain as mild or virulent. In addition to the common mosaic viruses, two other viruses were found to induce chlorotic leaf symptoms on apple ; one a ring-spot virus identified in plum, and the other found in a Malling II rootstock showing a vein-clearing leaf symptom. The latter failed to produce any recognizable symptom when transmitted to other rootstocks.

In the work of indexing rootstocks and nursery sources of scion-varieties for Rubbery Wood virus, using Lord Lambourne as indicator, some 6,000 Malling II rootstocks were double grafted, and 8,000 double budded, by the nursery staff. The propagation of virus-tested clones of the commercial Malling rootstocks proceeded, and some positive results were obtained in the search for an indicator of Rubbery Wood virus giving visual, rather than tactile, macro-symptoms.

Pear.

Experiments with this host were mainly directed to finding indicators of pear viruses more sensitive than are quince seedlings, as the latter do not develop symptoms in the year of infection.

Cherry.

From this year's results it is clear that the mazzard clone F12/1, and Morello seedlings, are valuable indicators of cherry viruses. It has also become evident that a great variety of viruses are present in sweet cherry, and the precise description and evaluation of each group of these presents a very complicated problem. Two facts emerge clearly, namely (*a*) that some varieties are virtually symptomless carriers even of the more severe viruses, and (*b*) that Rusty Mottle is very widespread in many varieties, with and without the expression of symptoms. The search for virus-free scion sources also continued with varied success.

Plum.

Some eight virus diseases of plum are being analytically studied, together with those of cherry, since some viruses are common to both hosts. Extensive indexing is in progress to assess the degree of virus infection in plum rootstocks with the object of propagating healthy clones. Similar work is also proceeding on sources of scion wood for foundation stocks.

Strawberry.

Joint experiments with the Entomology Section were continued on the pattern of natural virus-spread in a Research Station strawberry plantation, and its modification by insecticides. The seasonal phases of spread are being determined by the consecutive exposure of batches of normal indicator plants (*F. vesca*) for two-weekly periods.

A virus disease of strawberry in plantations of the Climax variety, the Green Petal disease, was newly identified this year. From early experiments in vector determination negative results were obtained with the common Strawberry Aphid (*Pentatrichopus fragaefolii* Cock.). Another newly identified virus, associated with the Yellow-edge Crinkle complex and readily transmitted by *P. fragaefolii*, was first isolated from certain of the Cambridge Seedling series and from degenerate Climax

plants. It produces characteristic symptoms on, and is highly necrotic to, *F. vesca* and Royal Sovereign plants.

Heat-therapy investigations have progressed considerably and have yielded virus-free plants of certain important commercial varieties hitherto apparently totally virus-infected. Further work with possible chemotherapeutants merely yielded drastic necroses of the host varieties.

Bush fruits.

Some vector relationships of the Gooseberry Vein-banding virus (C292) were established, and an additional aphid vector to those already reported was discovered. No symptoms were expressed by black and red currant seedlings inoculated with this virus, and it is therefore probably not identical with either of those causing Vein-pattern and Yellows of black currant.

Fungicide investigations.

Apple Mildew.

This disease has greatly increased in severity in some areas in recent years, especially where alternative sprays have replaced the usual lime-sulphur in the post-blossom routine schedule. Among the new organic fungicides tested, only dinitrocaprylphenyl crotonate has so far given indications of good Mildew control, but commercial supplies of this are uncertain and the search for other satisfactory specifics continues jointly with the Plant Protective Chemistry Section. Some synthetic modifications of this fungicide were given a greenhouse test this year on rootstocks in pots. The effects on Mildew of certain modifications of the standard spray programme are also being investigated.

Fungicides.

In collaboration with the Plant Protective Chemistry Section, promising fungicides, among the synthetic organic chemicals tested at an earlier stage, were included in further plantation trials on apple and pear trees. The most satisfactory results against scab so far recorded were from SR 406 and a glyoxalidine preparation. One of the nitrosopyrazoles proved promising but the thiocarbamates tested were on the whole unreliable. Other materials were tested on dwarf-pyramid trees of commercial apple varieties.

Concentrate spraying.

This investigation of the possible use of low-volume spraying with concentrated lime-sulphur was continued on apple rootstock hedges, dwarf bush trees, and on established plantation trees on the Research Station plots, and, with the N.A.A.S., in two commercial plantations in Kent. A prototype spray-atomizing machine, made for the purposes of our experiments by the National Institute of Agricultural Engineering, was used this year for the experiments on established trees at the Research Station. A paint-gun operated by a power driven air-compressor again served for the smaller-scale material. Results at present available are promising but indicate a need for improvement in the distribution of the ' fog ' in the large trees. Other fungicides applied as concentrates also gave promising results (see page 132).

Spray injury.

The results of an investigation with the Pomology Section of the influence of the M.IX Crosses series of rootstocks on susceptibility to spray damage were published in the Annual Report for 1950 (page 132). The same trees are now being observed for any influence of these stocks on the incidence of scab on Cox's Orange Pippin scions.

PUBLICATIONS DURING THE YEAR.

CADMAN, C. H. and HARRIS, R. V. **Leaf Curl, a virus disease of raspberries in Scotland.** J. hort. Sci., 1952, **27,** 201-11 (C285).

—— —— **A lethal virus disease of Lloyd George raspberry in Scotland.** J. hort. Sci., 1952, **27,** 212-14 (C286).

CADMAN, C. H. **Studies of *Rubus* virus diseases. I. A latent virus of Norfolk Giant raspberry.** Ann. appl. Biol., 1951, **38,** 801-11 (C287).

MOORE, M. H. and KIRBY, A. H. M. **Can the new organic fungicides help the fruitgrower ?** Rep. E. Malling Res. Sta. for 1951 (1952), 200-4 (C288).

KEYWORTH, W. G. **Verticillium wilt of potatoes in Connecticut 1951.** Plant Dis. Reptr., 1952, **36**, 16-17 (C289).

POSNETTE, A. F. and CROPLEY, R. **A preliminary report on strains of the Apple Mosaic virus.** Rep. E. Malling Res. Sta. for 1951 (1952), 128-30 (C290).

——— **The Rubbery Wood virus and apple propagation.** Rep. E. Malling Res. Sta. for 1951 (1952), 131-2 (C291).

POSNETTE, A. F. **New virus diseases of *Ribes*.** Rep. E. Malling Res. Sta. for 1951 (1952), 133-5 (C292).

POSNETTE, A. F. and BOVEY, R. **Field studies on virus diseases of strawberries. I. The rate of virus spread in the variety Auchincruive Climax.** Rep. E. Malling Res. Sta. for 1951 (1952), 136-8 (C293).

MOORE, M. H. **An intensive field method for testing fungicides for apple trees.** Rep. E. Malling Res. Sta. for 1951 (1952), 139-47 (C294).

— **Note on infection of young peach shoots and of leaves by the Brown Rot fungus, *Monilia fructigena*.** Rep. E. Malling Res. Sta. for 1951 (1952), 148 (C295).

TALBOYS, P. W. **A method for the study of the effects of Verticillium toxins on the water relations of cut shoots.** Rep. E. Malling Res. Sta. for 1951 (1952), 149-51 (C296).

KEYWORTH, W. G. and HARRIS, R. V. **Diseases of the hop. Work at East Malling Research Station.** Nature, Lond., 1952, **169**, 644-5 (C297).

WOOD, C. A. and BOASE, M. **Fruit variety trials. I. A trial of ten varieties of raspberry at Forfar, Angus.** Scot. Agric., 1951-52, **31**, 159-67 (C298).

CADMAN, C. H. **Studies in *Rubus* virus diseases. II. Three types of vein chlorosis of raspberries.** Ann. appl. Biol., 1952, **39**, 61-8 (C299).

——— **Studies in *Rubus* virus diseases. III. A veinbanding disease of raspberries.** Ann. appl. Biol., 1952, **39**, 69-77 (C300).

MOORE, M. H. **Spraying for Apple and Pear Scab.** Grower, 1952, **37**, 789 (under different title). Fruitgrower, 1952 (April), 677 (unsigned note) (C301).

POSNETTE, A. F. **New vectors of strawberry viruses.** Nature, Lond., 1952, **169**, 837-8 (C302).

POSNETTE, A. F. and HARRIS, R. V. **Virus diseases of fruit crops.** Nature, Lond., 1952, **170**, 181-2 (C304).

KEYWORTH, W. G. **Root injury as a factor in the assessment of chemotherapeutants by the tomato *Fusarium* wilt test.** Ann. appl. Biol., 1952, **39**, 441-2 (C306).

HARRIS, R. V. **The maintenance of healthy fruit clones.** 13th int. hort. Congr., London, 1952 (in the press) (C307).

POSNETTE, A. F. **Virus diseases of cacao in West Africa : the present position.** 13th int. hort. Congr., London, 1952 (in the press) (C308).

MOORE, M. H. **Field methods for testing fungicides for apple and pear trees.** 3rd int. Congr. Pl. Prot., Paris, 1952 (in the press) (C309).

——— **Concentrate spraying in fruit plantations ; a review of experiments with lime-sulphur.** 3rd int. Congr. Pl. Prot., Paris, 1952 (in the press) (C312).

VI. ENTOMOLOGY

By A. M. MASSEE

Tree fruits.

Inoculations have been continued in the insectary to test the resistance of some apple seedlings of the parentage (Northern Spy × Laxton's Superb*) × Cox's Orange Pippin to attacks of the Woolly Aphid (*Eriosoma lanigera* Hausm.). Of the 152 seedlings tested, 54 per cent proved very susceptible early in the season and were discarded ; 41 per cent, while less susceptible, eventually broke down, and colonies of aphids were formed on each. The remaining 5 per cent were classified as highly resistant, and are being retained for further tests next season.

Eighty seedlings of the Malling-Merton series of rootstocks were tested for the third year, and all maintained their resistant qualities throughout the growing season. This confirms the results obtained many years ago with the same plant material.

Routine counts of capped blossoms of the Apple Blossom Weevil (*Anthonomus pomorum* (L.) Curt.) have continued on selected plots to observe the rate of reinfestation following the elimination of this pest in 1948.

A detailed study of the biology of the Winter Moth (*Operophtera brumata* L.) has been started. Observations indicate that even in unsprayed orchards and woodland in Kent, populations of this insect are at present very low. Greasebands, a mercury-vapour light trap, and other methods of collecting have been used to determine the flight period and time of activity of the moths. The time of hatching of the eggs was observed in the field and the insectary, and the sites of the fruit trees used for oviposition were noted. The development and feeding habits of the larvae were studied in conjunction with observations on the bud stage of the host plant.

The infestation of Pear Sawfly (*Hoplocampa brevis* Klug), a Continental pest which was first noted in 1949, was kept under observation, and control measures recommended. It was confirmed that the original outbreak has been eliminated, and the two further infestations noted in the vicinity have not spread during the season.

The Pear Sucker (*Psylla pyri* L.), also a Continental pest of some importance, has been noted in many pear plantations in Kent. Preliminary observations have been made on its life-cycle under field conditions.

The investigations on the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (C. L. Koch)) have again been continued at the Field Laboratory, Great Braxted, and also at East Malling. The first records of the hatching of the overwintering eggs were generally earlier than normal, but, despite this, hatching was not completed until late May and in some areas early June. In most Essex orchards four generations of mites were noted, but in a few plantations five generations were observed.

Direct mite injury to the foliage was noted at the end of May — a month to six weeks earlier than usual. The eggs of the first generation of mites were noted from mid-May onwards. Mite dispersal was seldom noted during the summer until the beginning of September.

It is of interest and importance to note that in many commercial orchards the summer population of mites was very low irrespective of the winter and summer sprays employed, and it was not until the autumn that severe mite infestations were noted.

The large-scale summer spraying trial was continued, with certain modifications, at the Essex Institute of Agriculture, Writtle, on an orchard of Laxton's Superb. Four acaricide/ovicide treatments were applied once at the end of May. All the treatments very considerably reduced the mite and egg populations, and, indeed, two of them so reduced the populations that few mites and eggs were present at the end of August and mite injury to the foliage was not apparent. The field performance of these spray chemicals is of great importance and draws attention to the value of combined acaricide/ovicide sprays when the timing of their application is properly assessed. Two of the treatments caused considerable injury to the fruits of Worcester Pearmain, the pollinator variety on the Laxton plot. Phytotoxicity tests of the sprays used in the main trial were also conducted on trees of the variety Cox's Orange Pippin, also situated at Writtle. These investigations have been conducted in close collaboration with the Plant Protective Chemistry Section.

Small field trials were also carried out with winter ovicides at Hatfield Peverel, and trials to determine the effect on the mite populations of BHC applied at different times in a cordon orchard at Braintree, Essex.

* Cox's Orange Pippin × Wyken Pippin.

A study of the beneficial insects associated with the Fruit Tree Red Spider Mite has continued. Predators of the mite were again scarce in the summer spraying trial orchard at Writtle, and observations on the effect of these acaricides and ovicides upon predators were made in another orchard where similar sprays were specially applied at a later date. Further records and observations have been made at Ryarsh, Kent, where the effect of various fungicides upon the Red Spider Mite and predator populations is being investigated.

Another trial, consisting of larger plots than at Ryarsh, has been started at Stondon Massey, Essex, using the same fungicidal treatments. Whereas at Ryarsh the treatments followed many years of commercial sprays, at Stondon Massey the experimental sprays are the first fungicides to be applied to this orchard.

Biological studies have been centred on the predatory mites, extensive observations having been made on the life histories and habits of the species most abundant on fruit trees. The many species of predatory mites involved are being identified, and their host plant range studied. Counts are being made in many orchards of the winter egg densities after applying various commercial spray programmes.

Detailed biological studies of the species of aphids infesting apple, pear, red and black currant, and gooseberry are in progress. Preliminary observations are being made on *Prunus* aphids, as material and time permit.

Field trials have been carried out to compare the efficiency of sprays applied shortly after the hatching of the winter eggs as against conventional winter washes.

More detailed information has been obtained of the biology of the Codling Moth, more especially in relation to the flight of the adults and the emergence, under different overwintering conditions, of the larvae. Further work has been carried out on the parasites. In one instance parasites emerging from collected larvae were liberated in the orchard to determine whether the parasite population can be increased.

A new summer spraying trial was carried out in the field in collaboration with the Plant Protective Chemistry Section.

The recently introduced mercury-vapour light trap has proved a very useful piece of research equipment. The flight period of many species of *Tortricid* moths which frequent the orchard has been accurately ascertained with the aid of the trap. Special attention has been given to the flight periods of the Summer Fruit Tortricid, *Adoxophyes orana* (F.R.). Work has also been continued on the biology of this Tortricid, the emergence of overwintering larvae, the feeding habits of the larvae, and the flight and habits of the adults having been studied.

Preliminary trials for the control of the winter and summer generations of the moth were carried out in collaboration with the Plant Protective Chemistry Section.

Observations have been made on the various types of damage caused by this new pest and of other agents causing similar injury to the fruits. Other *Tortricid* species have also been studied to ascertain their prevalence in the orchards, and whether they can be regarded as of economic importance. It was hoped to find a means of distinguishing the larvae of the various species, but at present it has not been found possible to tabulate a reliable key.

The incidence of the Meadow Nematode (*Pratylenchus pratensis* de Man) on the roots of top and soft fruit is being investigated.

Further insectary trials on the chemical control of the Red Bud Borer (*Thomasiniana oculiperda* Rueb.) have been carried out.

The biology of a cambium miner (*Dendromyza* sp.) on *Prunus* spp. is being studied in collaboration with the Pomology and Plant Pathology Sections.

Small fruits.

Studies on the biology of the Strawberry Eelworms (*Aphelenchoides ritzema-bosi* (Schw.) and *A. fragariae* (Ritz-Bos)), including field trials on persistence in soil and on population fluctuations, have been continued. Collaborative work with the Plant Pathology Section has confirmed results previously obtained on the etiological association between these eelworms and *Corynebacterium fascians* (Tilford) Dowson.

Further experiments have sought to determine the part played by the eelworm in the absence of bacterium and the effect, if any, of the bacterium on the biology of the eelworm.

Encouraging preliminary experimental results on the chemical control of the Strawberry Eelworms and the Stem Eelworm (*Ditylenchus dipsaci* (Kuhn)) are being followed up in further field and insectary trials.

Investigation on the Strawberry Aphid (*Pentatrichopus fragaefolii* (Ccl.)) have been continued, and field trials have been carried out to (*a*) compare the effect on control in runner beds of sprays

containing different concentrations of Schradan ; (*b*) evaluate the control in fruiting beds of tar oil applied during the dormant period and Schradan applied pre-blossom ; (*c*) study in conjunction with the Plant Pathology Section the incidence of virus following various spray treatments. Population counts have also been made on all Research Station plots receiving routine spray treatments to study the effects of these when applied under commercial conditions.

The Ground Beetles attacking strawberry fruits are being studied. Preliminary trials with DDT applied before and during the fruiting period proved unsuccessful. Attempts have been made to devise a satisfactory trapping method for population assessment.

A preliminary analysis of aphid honeydew has been made in an attempt to relate ant attraction to the chemical composition.

Trials of the effect of parathion and DDT on the control of the Black Currant Leaf Midge (*Dasyneura tetensi* (Rueb.)) and on fruit set have continued.

Systematic study of Gall Mites and Red Spider Mites.

The World Catalogue of the *Phytoptid* mites is being brought up to date, and the species of mites contained in the family *Parasitidae*, which are closely associated with the Fruit Tree Red Spider Mite, are being studied in detail.

Publications During the Year.

Pitcher, R. S. **Observations on the Raspberry Cane Midge** (*Thomasiniana theobaldi* **Barnes**). **I. Biology.** J. hort. Sci., 1952, **27**, 71-94 (D236).

Pitcher, R. S. and Webb, P. C. R. **Observations on the Raspberry Cane Midge** (*Thomasiniana theobaldi* **Barnes**). **II. 'Midge Blight', a fungal invasion of the raspberry cane following injury by** *T. theobaldi*. J. hort. Sci., 1952, **27**, 95-100 (D237).

Collyer, E. **Biology of some predatory insects and mites associated with the Fruit Tree Red Spider Mite** (*Metatetranychus ulmi* **(Koch)) in South-Eastern England. I. The biology of** *Blepharidopterus angulatus* **(Fall.) (Hemiptera-Heteroptera, Miridae).** J. hort. Sci., 1952, **27**, 117-29 (D238).

Blair, C. A. and Groves, J. R. **Biology of the Fruit Tree Red Spider Mite,** *Metatetranychus ulmi* **(Koch) in South-East England.** J. hort. Sci., 1952, **27**, 14-43 (D239).

Dicker, G. H. L. **The biology of the Strawberry Aphid,** *Pentatrichopus fragaefolii* **(Cock.), with special reference to the winged form.** J. hort. Sci., 1952, **27**, 151-78 (D245).

Groves, J. R. **A preliminary account of the Summer Fruit Tortricid,** *Adoxophyes orana* **(F.R.), in Great Britain.** Rep. E. Malling Res. Sta. for 1951 (1952), 152-4 (D248).

Massee, A. M. **Notes on some interesting insects observed in 1951.** Rep. E. Malling Res. Sta. for 1951 (1952), 155-61 (D249).

—— **Transmission of Reversion of black currants.** Rep. E. Malling Res. Sta. for 1951 (1952), 162-5 (D250).

Dicker, G. H. L. **Studies in population fluctuations of the Strawberry Aphid,** *Pentatrichopus fragaefolii* **(Cock.). I. Enemies of the Strawberry Aphid.** Rep. E. Malling Res. Sta. for 1951 (1952), 166-8 (D251).

Dicker, G. H. L. and Briggs, J. B. **Results of some experiments to control Winter Moth and Tortricid larvae on apple.** Rep. E. Malling Res. Sta. for 1951 (1952), 169-71 (D252).

—— —— **A note on the Small Ermine Moth,** *Yponomeuta padella malinella* **Zell.** Rep. E. Malling Res. Sta. for 1951 (1952), 172-3 (D253).

Groves, J. R. **Supplementary measures for the control of Codling Moth,** *Cydia pomonella* **(L.).** Rep. E. Malling Res. Sta. for 1951 (1952), 174-8 (D254).

Hill, A. R. **Observations on** *Lygus pabulinus* **(L.), a pest of raspberries in Scotland.** Rep. E. Malling Res. Sta. for 1951 (1952), 181-2 (D255).

Paine, J. **A list of insects occurring on the hop.** Rep. E. Malling Res. Sta. for 1951 (1952), 179-80 (D256).

Massee, A. M. **Fluctuations in orchard faunae.** 13th int. hort. Congr., London, 1952 (in the press) (D257).

VII. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Laboratory investigations.

Work has proceeded along much the same lines as in the previous year, but attempts have been made to breed the summer forms of the Fruit Tree Red Spider Mite throughout the year with a view to providing standardized material for the biological assay of chemicals.

Ovicides.

Further studies on the role of ionization of DNC included dipping of eggs of *Aphis pomi* Deg. in formulations of DNC (0·0035 per cent) which had been buffered to pH 4, pH 7, or pH 10. The changes in susceptibility of winter eggs (greenhouse laid) of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* Koch) towards azoxybenzene were studied for two months (early February to early April). Studies were also made with this toxicant at various temperatures, concentrations and with varying amounts of emulsifier. Four benzyl benzoates, nine phenyl benzenesulphonates, and two new organophosphorus compounds were tested at 0·1 per cent. The range of activity of dinitro-*sec*-butylphenol (DNBP, dinoseb) was studied. The summer eggs of this mite seem to become more resistant to the ovicide, diphenyl sulphone, as they get older.

The failure of an attempt to obtain accurate dosage/toxicity data for diphenyl sulphone and four phenyl benzenesulphonates led to the study of the environmental conditions best suited for maintaining the eggs after dipping. Summer forms of this mite have been reared continuously indoors from the autumn of 1951 onwards, but the present arrangements are not adequate, either qualitatively or quantitatively, to provide a range of organisms in sufficient numbers for comparative testing.

Insecticides.

Experiments have been made on the effect of DDT on *M. ulmi* to throw light on the problem of the increase in populations of this mite in orchards receiving DDT in the summer.

Comparisons of the activities of certain organo-phosphorus compounds have been made. Parathion, E605 (Bayer), and malathon (the suggested coined name for S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate) were compared by injection in locusts (*L. mig. migratorioides*), formulated in modified Ringer's solution plus acetone and Lissapol NX ; the two parathion preparations gave identical effects, but malathon was much less toxic. Towards *Tribolium confusum*, the O,S-diethyl isomer of parathion proved equitoxic with parathion by contact effect, both at 5 mg. and 1 mg. per slide ; the compound malathon, tested in this way, appears to have an LD_{50} about twice as large as that for parathion.

Malathon was compared with parathion on two other pests. A new technique was used for testing the residual effect of these compounds against adult females of *M. ulmi*, and showed that about 0·025 per cent malathon was necessary to cause the same percentage mortality in the same time as did 0·01 per cent parathion. A similar ratio was found to hold for colonies of *Aphis pomi* Deg. on rootstocks with a dipping technique.

Fungicides.

Considerable work has been done on the slide-germination method of assay using *V. inaequalis* ; much of this was reported to the 3rd International Congress of Crop Protection in Paris in September, 1952 (see page 161).

Several groups of compounds were examined during the year. Zinc ethyl xanthate appeared to be considerably more toxic than the sodium salt, and a similar differentiation was found between *o*- and *p*-hydroxy-diphenyls. No significant activity was shown by several organosulphur compounds, including S-benzthiazyl N-cyclohexyl sulphenamide which is related to SR406 (S-trichlormethyl N-tetrahydrophthalylsulphenamide).

Spray damage.

Collaboration with the Physiology Section has been continuous throughout the year. Work on a method of estimating the efficiency of wetting agents on hairy leaves has been continued, but no means was found of reducing the heterogeneity of the observations, although suitable experimental designs were elaborated to render comparisons more accurate.

The method of measuring scorch on raspberry leaves reported last year was successfully employed on apple trees in the greenhouse and even in the field, although variability was greater in the outdoor material and replications had to be increased. All wetting agents studied had a marked effect on the volume of liquid required to achieve complete wetting, but very little on the quantity retained by a hairy leaf surface. With copper sulphate, one agent led to more damage than another, working at the same wetting efficiency.

A study has been commenced of the effects of chemicals likely to cause damage when applied as concentrates in small volumes.

Organic chemistry.

Twenty-one compounds were prepared in small quantities, and others purified, for biological evaluation. Larger quantities were prepared of several 4-nitrosopyrazoles ; these were used in field studies of fungicidal and phytocidal action.

Formulation.

As far as possible, materials for field use (and almost invariably for laboratory use) have been formulated in the Section ; considerable attention to this aspect has been found necessary.

Chemical analysis.

It was found that mixing the glyoxalidine fungicide 341 with the usual concentration of lead arsenate in tap water and with the recommended 8 oz. slaked lime per 100 gallons, released more soluble arsenic than was present in the lead arsenate suspension alone, but considerably less than was released by the addition of 1 per cent lime-sulphur to the lead arsenate suspension.

Unexplained losses of mercury still impede the work on mercury residues. Some results were obtained which indicated the rate of weathering of phenyl mercury chloride, applied as a china clay formulation, on leaves of Worcester Pearmain, and it is hoped to get figures for the residues on fruits.

The Alessandrini method of estimating DDT deposits was modified slightly and used to estimate residues of DDT on bark ; micro-cells in the Spekker absorptiometer were required for values in the region of 1-20 μg. Rootstocks were sprayed with DDT wettable powder alone and with various commercial spreaders added to determine the effect on run-off, i.e. on initial deposit, and on the subsequent rate of loss by weathering. Assessment of another proposed method of estimating DDT residues is also in progress.

Greenhouse investigations.

The fact that so few of the new fungicides, offered for use in place of lime-sulphur, give any control of Apple Mildew has led to an attempt, in collaboration with the Plant Pathology Section, to develop a greenhouse method of assaying chemicals against this disease. The use of M.III rootstocks grown in pots and dipped in formulations of the chemicals to be studied appears promising.

Field investigations.

Most of the previous year's trials were continued in collaboration with the Entomology and Plant Pathology Sections. The fungicide-predator studies were extended to Essex, and new trials established on the control of the Summer Fruit Tortricid.

Insecticide trials.

Codling Moth.—Toxaphene, used both with and without a synthetic sticker, was compared with DDT and with lead arsenate.

Summer Fruit Tortricid (*Adoxophyes orana*).—As an emergency measure, trials were carried out on two farms in East Kent. Comparisons were made of the effectiveness of various applications of DNC and/or DDT against the first generation, and of parathion, with and without DDT, and toxaphene against the second generation.

Fruit Tree Red Spider Mite.—The summer trial at Writtle was of single applications of mixtures of two summer ovicides, DPS or CPBS, with one or other of two acaricides, parathion or benzyl benzoate. Neither acaricide appeared to confer any advantage over the other, but mixtures containing CPBS provided freedom from build-up for longer than did mixtures containing DPS. On the other hand, in contrast to the 1951 results, CPBS with either acaricide was associated with splitting of many Worcester Pearmain fruits a month or more after the date of application. No damage was

seen on Cox's Orange Pippin leaves or fruit, and only some russeting on Laxton's Superb. DPS caused no significant damage in this trial.

A small winter trial was again conducted to assess the value of dinoseb (DNBP), with or without a synthetic sticker, as compared with the usual DNC-petroleum wash. The results were not encouraging.

The predator aspect.

The trial begun at Ryarsh, Kent, to study the action of a number of fungicides and insecticides upon certain predators, especially Typhlodromid mites, was continued, the insecticide aldrin being dropped in favour of fungicide J49.

A new trial was set up at Mellow Purgess Farm, Stondon Massey, Essex, where a hitherto unsprayed orchard was placed at our disposal. Here large blocks are being used with only two replicates to minimize the effects of migration ; only three fungicides—lime-sulphur, 341, and SR406—are being applied.

Fungicide trials.

Pear Scab.—The comparisons of new fungicides with a lime-sulphur/dispersible sulphur schedule were continued on three varieties. No damage was seen even on Doyenné du Comice but scab incidence was slight except on Williams' Bon Chrétien.

Apple Scab.—Comparisons of fungicides with 1 per cent lime-sulphur were continued on dwarf pyramids of four varieties, and trials of the most important new materials were compared with a full lime-sulphur schedule on bush trees at the Station and on large trees on a commercial plantation. SR406 was outstanding and 341 was also very effective. Metallic dithiocarbamates and bisdithiocarbamates were effective only at high dosages.

Apple Mildew.—The value of certain fungicides for the control of mildew on apple rootstocks has been studied. No damage to Lane's Prince Albert resulted from the use of a wettable powder formulation of dinitrocaprylphenyl crotonate for the control of this disease.

Spray damage.

The first of the new phytotoxicity plots has been planted up and apples, pears, gooseberries, and black currants were available for tests. A large programme was carried out on this plot, and studies of the effects of formulation on the damage caused by certain mite summer ovicides were made on other plots.

Publications During the Year.

Kirby, A. H. M. **The chemical control of the Apple Sawfly.** Ann. appl. Biol., 1951, **38**, 899-903 (Q65).

Kirby, A. H. M. and Bennett, M. **Spray damage investigations in 1949-51.** Rep. E. Malling Res. Sta. for 1951 (1952), 183-6 (Q66).

——— ——— **An effect of phenyl mercury chloride on pear leaves.** Rep. E. Malling Res. Sta. for 1951 (1952), 187-8 (Q67).

Kirby, A. H. M. **Recent developments in the chemical control of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* Koch) in south-east England.** 3rd int. Congr. Pl. Prot., Paris, 1952 (in the press) (Q69).

Kirby, A. H. M. and Frick, E. L. **The glass-slide germination technique as a simple, precise tool for toxicity studies with *Venturia* spp.** 3rd int. Congr. Pl. Prot., Paris, 1952 (in the press) (Q70).

VIII. SCIENTIFIC LIAISON SECTION

By H. B. S. MONTGOMERY

During the specially busy period of April to July the Section was short-handed, due to the absence of the writer in the United States on a special fruit course arranged under the auspices of the Mutual Security Agency. In spite of this the volume of correspondence dealt with was approximately the same as in the previous year. Analysis of the correspondence showed that 1,520 letters concerned advisory enquiries and 820 referred to visits, exhibits, lectures, and related matters. Individual visitors from overseas were particularly numerous this year, the number, 382, doubtless being swelled by many delegates to the Thirteenth International Horticultural Congress in London. Some 170 were specialists and many of these stayed for several days. In all, omitting Members' Days and special courses, just over 2,050 visitors were received.

Four Members' Days enabled members to keep in touch with the research on propagation, hops, virus diseases, and the new apple rootstocks. The attendance on each occasion was over 100, totalling 500 altogether. Two of these days were arranged to fit in with the fourth and fifth Amos Memorial Lectures, and on these occasions officers of the Advisory Services were invited to attend. The rehearsals that preceded the other two Members' Days were well attended by advisory officers, and provided opportunities for mutually helpful discussions. Some 200 people from the districts near the Research Station attended the Local Day, held on a Saturday afternoon in June.

Assistance was again given in editing and in proof reading the Annual Report. In addition, time has been spent on the production and revision of the official fruit bulletins in collaboration with the N.A.A.S.

All members of the Section have been active in lecturing on various aspects of the work of the Station ; thirteen talks were given at centres in Berkshire, Cambridgeshire, Hampshire, Hertfordshire, Suffolk, West Sussex, and Wisbech, as well as in Kent.

An exhibit based on research on the root systems of apples was prepared for the Chelsea Flower Show. It centred around three scale models of trees and root systems of Cox's Orange Pippin, on M.I, M.II, and M.IX respectively, that had been excavated at Faversham, and the exhibit included monoliths of the soil profile on the plot. This exhibit was also shown at the Cobdown Show. Assistance was given to the N.A.A.S. in staging one of these excavated trees at the N.F.U. Market Produce Show at Reading as part of their exhibit on the maintenance of soil fertility. Help was also given to the N.A.A.S. in the preparation of their exhibits at the East Kent Fruit Show and the Kent County Show. Members of the Section judged fruit at Marden, East Kent, Platt and Cobdown.

The usual contacts with the advisory services were maintained. Altogether some 300 advisory officers visited the Station in parties or as individuals. County and provincial experiments have led to frequent consultations and discussions with the Section on treatments and experimental procedures.

The various activities of the Section for the direct service of the research staff have been kept up and the normal series of lectures for the plantation assistants organized.

Members of the Section devoted a part of their time to specific research projects, especially studies on peach culture (see page 21) and on root excavations (see page 23).

Publications During the Year.

Montgomery, H. B. S. **Research in fruitgrowing at the East Malling Research Station.** Times Sci. Suppl., Autumn 1951, 5-6 (T38).

——— **Blossom thinning by sprays.** N.A.A.S. quart. Rev., 1952, No. 15, 109-10 (T39).

——— **Rootstock/scion incompatibility.** N.A.A.S. quart. Rev., 1952, No. 16, 165-7 (T41).

Part III

RESEARCH REPORTS AND REVIEWS

AMOS MEMORIAL LECTURE*

RESEARCH DEVELOPMENTS IN FRUIT CULTURE IN AMERICA

By H. B. TUKEY

Head, Department of Horticulture, Michigan State College, East Lansing, Michigan

It is, indeed, for me a privilege and an honour to meet with you and to present to you the fifth in the series of lectures in recognition of your countryman and colleague, Mr. J. Amos. It is a generous thing you do in thus keeping his memory alive, and in emphasizing that for which he stood, namely, the entwining of the scientific and the practical in fruitgrowing.

Those of us from across the seas who come to your shores to see what you are doing and how you do it (and we learn a great deal), as well as to enjoy your most excellent hospitality and gracious living, observe your horticulture with great respect. Over a period of generations many of you have developed an understanding of plants and how they grow, which is as though you had become a part of the plant and were able to thread your way in and about it as easily and with as much understanding as you would your own homes. Some people have dubbed this ' experience ', ' common sense ', or the ' green thumb '.

And while all of this is fine, there are not enough craftsmen with the green thumb to satisfy all needs. Further, while the green thumb may have its virtues, it may also have its faults. My father-in-law tells a story that illustrates the point. One of the good neighbours a mile or so down the road had an intelligent young daughter, Sarah, who came to the house now and then to help with the cooking. And when Sarah cooked a ham, she invariably cut off the shank portion. Asked why she did this, she replied ' Because mother always cooks a ham that way '.

The next time my father-in-law visited the neighbours he thought to ask why Sarah had been taught to cut the shank from the ham when she cooked it. At which the mother went straight to the kitchen, returning smilingly with a small pan in her hands, to say, ' You see, we always cut off the shank because we did not have a pan large enough to hold a *whole* ham ! '

And so, sooner or later, we invariably turn to some system whereby the art and the folklore of a subject may become tested, rationalized, and catalogued, so that it can be handed to a great number of men for use. This is particularly so in America, where the exactitudes of conquering and subduing a Continent have left little opportunity for some of the qualities which only time provides. The tendency in America has been to work as much as possible, therefore, by rules and handbooks and charts and tables as the engineer would do when he builds a bridge, so as to remove the guess work and the gamble.

From this has come a sort of ' biological engineering ', or in our case ' horticultural engineering '. It is all based on research and the research method, which is essentially a careful or critical search for knowledge, participated in and enjoyed by many, and I would emphasize this, trained scientists, professional horticulturists, fruitgrowers, and amateurs alike. It has come alive all over the world. And, while I will speak mostly of American research, you must appreciate, as do we, that science knows no geographical or political boundaries, and that you here in England have made outstanding contributions to horticultural science. Time does not permit me to pay more than formal recognition to the outstanding achievements from East Malling, Long Ashton, and a dozen other places.

* The fifth Amos Memorial Lecture, delivered at East Malling Research Station on 25th September, 1952, before an audience of some three hundred.

Happily, there is already a good start towards 'horticultural engineering'. The creation of improved varieties of fruits is an example. In the past left largely to chance, new varieties are now made to order for particular needs. The V-peaches from Canada ; the Golden Jubilee, Ambergem, and a score of other peaches from New Jersey ; the Cortland apple, the Stanley plum, and the Catskill strawberry from New York ; the series of Haven peaches from Michigan ; the new clingstone peaches from California ; the Latham red raspberry from Minnesota ; the Klondike strawberry from Louisiana —these are all products of scientific plant breeding. Fifty-five per cent of strawberry production, 75 per cent of red raspberry production, and 90 per cent of blueberry production is represented in varieties created by scientific effort.

The plant breeder has been given new tools by geneticist, cytologist, chemist, and plant physiologist. He has learned that many fruits are truly monstrosities, or chimaeras as they are properly called. A chimaera, as you well know from mythology, possessed the head of a lion vomiting flames, the body of a goat, and the tail of a serpent ! Some bud sports, many variegations, and such odd fruits as the Sweet-and-Sour variety of apple, with one portion sweet and an adjacent portion sour, are now explained as chimaeral, and composed of a mixture of tissues of varying genetic make-up—not the uniform, solid, simple creation we have often surmised. Small wonder we have had difficulties in the past in understanding the vagaries of some of our fruits.

The plant breeder has learned, also, that certain varieties when used as parents tend to stamp their offspring with desirable characters, while others are inferior sires. He knows that the Deacon Jones apple transmits size, that the Mills grape transmits high quality, and that the Lloyd George red raspberry, which you well know, and the Premier strawberry are superior as parents. On the other hand, the Baldwin and Rhode Island Greening apples and the Seckel pear, though desirable in themselves, are most inferior parents.

By means of a drug (colchicine) from a species of crocus, he has been able to alter the number of chromosomes in plants when he needs to do so for breeding purposes. By performing a Caesarian section on immature fruits, removing the partially developed embryos, and culturing them like incubator babies, he has succeeded in making heretofore impossible crosses. By the use of certain growth-regulating chemicals he can prevent abscission of the flower until fertilization has been effected. He can work out the mechanism of heredity, and he can breed varieties to meet local needs, market changes, and shifts in consumer preferences. If enough facts were known about the plant with which he is working, he could put factors together to make a desired individual just as the organic chemist synthesizes new compounds. All this is coming, some of it is already here.

It may not be out of place to comment on the importance of the variety and of those who serve by the creation of improved sorts. The variety is the keystone of the industry. It is to the fruit industry what the new model is to the automobile industry. Until the Concord grape, there was no grape culture in America worthy of the name. The Bartlett (Williams') pear is the basis of pear production, and the Montmorency cherry is virtually the entire sour cherry industry.

In Michigan prior to 1920 there were hundreds of acres of unproductive land on which lived families of low income. The creation of new varieties of blueberries by scientific plant breeding has developed an industry now approaching two million dollars in annual crop sales. A breeding programme in apricots promises to establish an apricot industry, and a red-centred strawberry suited to south-western Michigan will ensure the maintenance of canning and freezing outlets. It is apparent that plant breeding must become increasingly more local. The general-purpose variety is useful, and that is what we aim for, but the future implies a variety not necessarily for a Continent, nor for a large region, but rather for a given purpose in a restricted locality. It implies breeding, not alone for specific details of improvement, but with great imagination for entirely new industries.

A few years ago, pollination and fruit set were little understood by commercial fruit growers, and their importance was poorly appreciated. Compatibilities and incompatibilities are now better known. No one to-day would plant a solid block of Delicious apples, Bartlett pears, Windsor sweet cherries, or J. H. Hale peaches without providing for effective cross-pollination ; and he would not use as pollenizers such triploid varieties as Gravenstein and Baldwin, which have defective pollen. This has been the product of research.

And when it comes to the pollination of fruit plants, the bee may be used as the agent with some regard to temperature, bee flight, and number of bees required for a given area. Traps have been devised so that pollen is scraped from the creatures as they enter the hive loaded with pollen. In turn this pollen has been placed in trays at the hive egress, so that bees emerge coated with proper pollen ready for business. Hand pollination has been found practical in some areas, and shot-gun shells loaded with pollen have been fired with some success at trees in the unfortunate modern tempo of treating everybody and everything as an adversary !

In recent years, however, securing a set of fruit has become less of a problem generally in America than thinning off of excess fruits. Here it has been found that early thinning is most effective,

beginning with blossom thinning. It is interesting to note in this connection that as long ago as 1835, Robert Manning of Salem, Massachusetts, one of America's early pomologists, found that by removing all the blossoms from some biennially bearing apple trees and not from others, he caused some trees to fruit one year and others the next, thus ensuring fruit each year. However, thinning of fruit by hand is now largely a thing of the past. In its place are chemical thinning and pole thinning of various types, in which blossoms and young fruits are literally beaten or brushed crudely from the trees.

Thinning of apples by means of blossom thinning sprays has become standard practice in large areas, and there is some success with peaches from applications several weeks after bloom. Dinitrocresols have been used in some regions, but growth regulators, such as naphthaleneacetic acid, have been found more effective in others. It has been learned that such sprays tend to ' knock off ' the weak blossoms and leave the strong, so that the quality of the remaining fruit is improved both by reduction of competition, and by ' the survival of the fittest '. The concentration of the chemical is adjusted to the variety, the season, and the vigour of fruit buds. That is, stronger concentrations are used with varieties which characteristically set heavily, with trees with vigorous fruit buds, and in seasons where weather at blossom time is highly favourable to fruit set. Weaker concentrations are used under the opposite conditions. Blossom thinning has proved one of the most effective agents in maintaining annual production in American apple orchards. Yet there is a feeling in some quarters that the fruit industry will be better served by the use of solid blocks of a single variety of small controlled trees upon which the blossoms are caused to set where desired, rather than removed by somewhat uncertain means after they have set.

To this end, studies with growth-regulating chemicals have shown some possibilities. For example, the Kadota and Mission varieties of fig commonly set fruit parthenocarpically, whereas the Calimyrna variety requires pollination and fertilization. Yet this last named variety can be caused to set fruit parthenocarpically by the use of certain growth regulators and without the aid of the caprifying wasp. It now appears that the varieties which set fruit without resort to pollination have a higher content of native hormone than does the Calimyrna. Research shows that fruit set and fruit development is related to liberation of specific hormones by pollen, by endosperm, by embryo, and probably by other parts. Extracts of corn pollen and of corn embryo will set tomato fruits. It is not too much to expect that the research worker will in time appear with methods of controlling fruit set more exactly. We look to you in England to provide some of the answers in this field in which you have already made significant progress.

Research in the field of growth regulators has made, and is making, contributions to the fruit industry equal to, if not greater than, any other field of endeavour at the moment. Not only are blossoms and fruits thinned, but the time of blossoming may be delayed by employing maleic hydrazide, more especially in the case of the raspberry. No practicable method of delaying fruit blossoming of tree fruits has yet been devised, but the possibilities are there. Sprays of certain growth regulators applied to developing figs at the proper time cause them to ripen earlier, as desired. The strawberry fruit develops because of the diffusion of growth regulating materials from the achenes which dot its surface. About the sixteenth day after bloom, the supply of growth regulator is low. Additional amounts of synthetic regulators applied at about this time apparently induces continued growth and increased size. It has been suggested jokingly that the future may see but one variety of fruit in a class, as one apple and one pear, caused to mature appropriately by chemical means as market demands dictate !

2,4,5-Trichlorophenoxypropionic acid causes apples not only to ripen early, but also to colour early. But success has been uncertain. Fortunately, the material is the most effective yet discovered for reducing pre-harvest drop. 2,4-Dichlorophenoxyacetic acid is specific and effective in this regard with the Stayman and Winesap varieties, but curiously ineffective with a number of other varieties.

2,4-D is also a potent herbicide. It has been found of value in controlling broad-leaved weeds in strawberry beds, the strawberry being resistant to the chemical. Other compounds, such as trichlorophenoxyacetic acid, are helpful for grass control, *iso*propylphenylcarbamate for control of chickweed, and EH-1 in pre-emergence treatments. Another interesting possibility is the destruction of strawberry runners by chemical means, thus permitting retention of the old bed for longer periods of high productivity.

Matters of soils, location, and site are perhaps now as well understood as any aspect of fruitgrowing. It is known that certain areas are suited to peaches, others to pears, and so on. Yet too much of this has been learned by bitter experience. The new technique is to study adaptation by controlled experiments. Thus, branches of trees are enclosed in cooled and in heated chambers to simulate different climatic conditions. It is found by this means, for example, that sour cherry fruits grow rapidly at high night temperatures for a period immediately following full bloom, but that they develop slowly, with low quality, and with poor colour, if the night temperatures are high late in the

season as the fruit is maturing. The adaptation of the sour cherry to such areas as northern Michigan, Wisconsin, and New York is thus established as in part due to warm early summer temperatures coupled with cool night temperatures prior to harvest.

Further, plants are grown in large constant temperature tanks where the root temperature can be properly maintained. With a root temperature of 45° F., strawberry plants require less fertilizer for the production of the same amount of dry weight than they do at 75° F. When it is realized that there may be as much as 30 degrees difference between the temperature of soil under mulch and under clean cultivation such information has real significance. In this connection, an interesting bit of research dealing with the tomato may not be out of place. It has been found that tomato flowers set as fruit only when night temperatures are above 59° F. Accordingly, by watching the night temperatures and then computing the number of days required from fruit set to maturity, one can predict when the tomato market in a given region, such as Detroit, will receive a liberal local supply of tomatoes. Going one step further, one need only sit in an easy chair, with thermograph, pencil and paper, and predict the date for price collapse of tomatoes on the Detroit market ! This has actually been done. This is ' biological engineering '.

Delayed dormancy of fruit trees is another problem in adaptation which has been met by research. Considerable distress has been experienced in southern sections in some seasons with delayed and scattered foliation and blossoming and attendant financial reverses. Varieties of tree fruits for the South are now catalogued as to the amount of chilling required to break dormancy. Further, breeding programmes recognize these facts and have successfully developed varieties of peaches, for example, adapted to southern California and to other southern regions.

Studies of length of day in relation to crop production have also provided valuable assistance to the fruit industry. The arguments and failures of a decade ago have disappeared with the knowledge that some varieties of strawberry tend to form flower buds in long days and are therefore successful in northern regions, whereas other varieties form fruit buds in shorter days and so are adapted to other regions.

Work of this kind may be expected to reveal much regarding adaptation of varieties, responses to growth regulators for blossom thinning and pre-harvest drop, colouring of fruit, and development of good finish in association with various spray materials.

As regards fertilizer and fruit tree nutrition, the case no longer rests with chemical analysis of the soil alone. Analyses of the tissues of the plant have been found valuable to supply additional information. The use of nitrogen has become fairly well standardized with either fall applications or early spring applications. But, as dependence has been placed largely upon nitrogen, other materials have been found of increasing importance, such as phosphorus and potassium. Various other deficiency troubles also have been identified, and have been corrected by the application of specific materials, as the little-leaf disease of citrus with zinc, and the internal corking of apples with boron. The trend now is to use leaf analysis by the spectrographic method for large-scale surveys of nutritional status and as the basis for rapid determination of plant needs. Balance between various elements is receiving considerable attention as, for example, the relation between calcium and boron, in which boron aids in the efficient use of calcium.

Perhaps the outstanding contribution to general orchard management practices has been the use of mulches. While first found beneficial in apple orchards, they have since proved of value for pears and to a limited degree for peaches and cherries. The writer, just for the interest of it, made a small planting of strawberries and red raspberries directly in a blue grass sod with no ploughing or cultivation, and has maintained it for several years solely by heavy mulching, never using a spade or shovel or hoe. Minor element deficiencies have tended to disappear under mulch, potash and phosphorus have become more readily available, and moisture supply has been increased. Associated with mulching are improved soil structure, better aeration, and increased penetration of rain. The mulching materials used are usually spoiled hay from a nearby farm, bearing out the axiom that ' it is an ill wind that blows nobody good '. Mulching has proved ' better than we know ' and has been one of the major shifts in orchard management in America.

As the appraisal of nutrition becomes more refined and more exact, there is considerable interest in foliar sprays. Such deficiencies as manganese, magnesium, zinc, and boron have been corrected by foliage applications. Further, it has been shown that bark applications may be effective under certain conditions. Sprays of nitrogen, mostly in the form of urea, have proved valuable supplements to soil applications. Urea is easily applied in the regular spray programme and may be absorbed in a few hours. It may be applied to apple trees early in the spring in delayed dormant and pre-blossom sprays when this element is needed to assist in fruit set. Additional sprays may be made if the season so requires. Such a ' wait-and-see ' programme tends to the production of fruit of high colour, since no excess of nitrogen is permitted as maturity approaches.

Not all fruit plants respond equally well to sprays of urea. Apparently there is a relation between

toxicity to urea and response from it. That is, the peach and cherry respond very little and will withstand concentrations of 10 to 20 lb. of urea to 100 gallons of water. The plum responds next in order, and will tolerate 8 to 10 lb. The pear responds slightly less than the apple, and will withstand 6 to 10 lb. For the apple, about 5 lb. is correct. The grape responds readily, and will tolerate only 3 to 4 lb.

An old bit of research, which still lays a heavy and controlling hand (some might even say a dead hand) upon much horticultural thinking and practice, is the so-called carbohydrate-nitrogen relationship. It is worth repeating here because, though it may represent an over-simplification or only a partial statement of the truth, it nevertheless is a good example of the synthesis of research into a working hypothesis—more of which we to-day so badly need. In American terminology we say ' it works ' and let it go at that. However, this does give the opportunity at this point to stress that in our quest for something new we in research have failed, too often, to put the pieces together into some framework of usefulness. The job is not done when the experiment is completed. It is done when it is made intelligible to others and can be used by them. This, then, is my excuse for introducing so elementary a topic as the carbohydrate-nitrogen relationship and one which, from the standpoint of the scientist, may properly be called naïve.

Simply stated, nitrogen is secured by the plant principally from the soil, and is influenced in amount and availability by temperature, soil moisture, root penetration, and other soil environmental factors. On the other hand, the carbohydrates are manufactured in the green portion of the plant from the carbon dioxide of the atmosphere in the presence of light. The general idea is that the ability of a plant to fruit is indicated by the relationship between carbohydrates and nitrogen in the plant.

On this basis, fruit trees may be placed in one of four classes as regards C-N relationship and fruiting :

Class I is the plant which has an abundance of nitrogen, but a deficiency of accumulated carbohydrates. It is the thin-wooded, spindly, weak tree that grows in the shade. It is like an undernourished child. It does not develop and does not fruit.

Class II is the adolescent, which, supplied with an abundance of both nitrogen and carbohydrates, keeps on growing exuberantly, with large dark green foliage, but does not get down to the business of fruiting.

Class III is the highly productive individual, in which sufficient reserve carbohydrates have accumulated to provide for fruit bud formation and fruiting. This is the age of maximum production and the joy of the successful fruitgrower.

Class IV is the age of senescence and decline, where carbohydrates have accumulated to such a degree that the foliage is yellowish in colour, the tree biennial in bearing, and the characteristics of age appearing—not unlike the man who accumulates sufficient avoirdupois to be termed ' a bit heavy ' or even ' corpulent ', and who is content to sit by the fire in his slippers, except for sporadic outbursts of enthusiasm from time to time which slowly diminish.

With these four classes clearly in mind, it has been shown that much can be done in the fruit plantation to control the behaviour of a tree. The weak tree of *Class I* needs to be brought into the sunshine, where it may manufacture more carbohydrates, pass into the adolescent stage of *Class II*, and there accumulate a sufficiency of carbohydrates to settle down into the productive period of middle life (*Class III*). Conversely, the ageing tree of *Class IV* can be rejuvenated and brought back into the productivity of *Class III* both by severe pruning which removes excess carbohydrates and by application of nitrogenous fertilizers, which increase the nitrogen balance.

Further, ringing and girdling are helpful in bringing a tree from *Class II* of adolescence over into the productive *Class III* by virtue of the fact that carbohydrates are induced to accumulate above the ring or girdle. Root pruning is similarly helpful, but for the reason that it reduces the intake of nitrogen. High summer temperatures may delay fruiting in young trees because the tree respires carbohydrates too rapidly to accumulate a sufficient amount for fruitfulness. Pruning a young tree excessively removes the carbohydrates, prevents accumulation, and tends to keep the tree in the weak, non-fruiting *Class II*.

Insect and disease attack and caustic sprays which injure the foliage all likewise tend to reduce the carbohydrate supply and delay fruiting.

Many mortals have recognized the similarity of all of this to the behaviour of animals and have dreamed wistfully, but forlornly, upon some method of rejuvenation, such as Ponce de Leon sought in the Fountain of Youth several centuries ago.

Research in rootstocks proceeds at only a modest rate for the reason that in general the seedling rootstocks employed have proved fairly satisfactory, in a situation where plenty of land and the call for tonnage production with less regard to quality and labour have made the advantages of the controlled tree less apparent. Yet there is now a growing demand for smaller than full-sized trees. To

meet this need with the apple, the Malling rootstocks have been tried with some success. They have proved adaptable to wide divergences of soil, rainfall, and summer temperatures. As a general rule, trees grow slightly smaller in America than they do on the respective rootstocks in England. The Malling IX is regarded solely for garden plantings. Malling VII is promising as a garden plant and perhaps also for commercial planting with vigorous-growing varieties. The Malling II is considered a reliable, general-purpose stock. Malling I seems useful for McIntosh in northern regions, but is suspected of susceptibility to collar rot in southern areas. Malling XIII seems useful for such precocious varieties as Golden Delicious and Cortland. Malling XVI has not been widely tried, but is considered of merit.

A second method of producing small trees is by the interposition of a short piece of body stock between the rootstock and the scion variety. For this purpose, a material known as ' Clark dwarf '* is being tried, especially where winter hardiness is a factor, and where some of the Malling rootstocks are not sufficiently hardy. The idea of the small, controlled tree offers some promise for problems of acute labour shortage, concentrate spraying, production of quality fruit, early fruiting, and shifts in varieties to meet changing market demands. The next step lies with fruitgrowers and sufficiently large commercial trials of trees controlled by the rootstock, to bring together the practical experiences of many.

Another important development in the control of environment has been the use of supplemental irrigation of the sprinkler type. Some arid regions have resorted to the seeding of clouds for the production of ' artificial rain ', but eastern regions where rainfall is between 25 and 40 inches have found a more exact control in irrigation. The new light-weight aluminium and plastic pipes, together with low-cost energy for pumping, have made irrigation most effective. Use has been confined mostly to strawberries, raspberries, nursery stock, and short-season crops. There is some question whether any measurable responses have been secured with tree fruits.

Fertilizers have been applied effectively in the irrigation lines, and some success has been observed in reducing injury to blossoms and fruit from late spring frosts. Various heating units have been devised for frost protection, including an infra-red heater employing oil as the fuel. Though valuable for low-growing crops on small areas at the rate of four heaters to the acre, they have not proved their worth with tree fruits, because of the shielding effect of branches. Further, the proper approach to the problem is the selection of frost-free sites, provided soil type and related aspects are suitable.

To study water relations in the soil, plaster of Paris and nylon blocks with electrical connections placed at varying depths, such as 6, 12, 24, 48, and 60 inches, have been found valuable. Readings are made on an inexpensive, direct-reading, portable meter which tells the soil moisture condition and indicates the need for moisture at different depths and positions in the orchard.

To discuss insect and disease control research at length would be an address in itself. Suffice it to say that never in the history of fruit production in America have insects and diseases been under such an excellent degree of commercial control. However, research in new materials and new methods of application continues. It has been shown that concentrate applications of 2, 4, or even 10 times are as effective when properly applied as the standard concentration. Research with virus diseases is being carried on very actively in regions where virus troubles are most severe, namely, the Pacific Coast States. Since you are leaders in the field of virus research, we turn to you for much assistance.

The discussion so far has been aimed primarily at problems of production. But the greatest change that has come to research in American fruit industry during the past decade has not been along the lines of production ; it has been along the lines of outlets, markets, and consumer acceptance.

This has been brought about by the tremendous competition between foodstuffs on the American market. In 1951 there were 125 different fruits and vegetables offered for sale in competition, 98 of these in larger than carload lots. Some of these products are relatively newcomers in quantity, such as escarole, dasheens, cranshaws, papayas, mangoes, kumquats, avocados, and prickly pears. The housewife is no longer required by necessity to take what is set before her, but may select what she wishes ; and she is a very shrewd and efficient buyer.

Studies of the purchasing activities of Mrs. Housewife and the retail store have revealed interesting facts. As an example, it has been found that in the Detroit market between November and February the sale of oranges averaged $32.00, and of apples $29.00, both together constituting two-thirds of the fresh fruit sales. Retailers set aside an average of 97 square feet of floor for display of fruits, of which 25 per cent was for apples. Apple sales averaged $1.19 for each square foot of display space. When the display space was increased 10 per cent, sales increased 4 per cent. A 2-lb. unit of sale moved less fruit than larger units up to 6 lb. Bulk displays placed alongside packaged displays increased sales as much as 35 per cent.

This is the kind of research and information which is being explained to fruitgrowers. The result

* ' Clark dwarf ' has recently been found similar, if not identical, to Malling VIII.

is that they are concerned as never before with matters of outlet and consumer acceptance. It is being realized that the channels of marketing are like a chain—a very poor instrument with which to push, but a very good one with which to pull. The movement of the chain begins when Mrs. Housewife buys something in the retail store. The pull is then felt clear back to the producer.

It has been found that the American diet has shifted remarkably in 40 years. The *per capita* caloric intake has declined from 3,500 to 3,200, expressed largely in reduction in consumption of potatoes by nearly a half, and cereals by nearly a third. On the other hand, there has been an improvement in the use of the so-called protective foods. Yellow, green, and leafy vegetables have increased about one-third. Fruits have increased about 14 per cent. Milk and dairy products have increased a third, and eggs have increased nearly as much.

Further, within the family of horticultural products there has been some shifting. The *per capita* consumption of apples was approximately 60 lb. 40 years ago, and is now about 26 lb. On the other hand, citrus has increased from 16 lb. to 50 lb. Interestingly enough and to the surprise of American fruitgrowers, the *per capita* consumption of watermelons is the same as for apples—26 lb. The consumption of lettuce is 21 lb., of celery 12 lb., of tomatoes 30 lb.

Another change has been the increase in processing of horticultural products. More than half of all the vegetables, and nearly half of all the fruits produced in America, are now processed in one way or another. Frozen foods, fruit juices, and prepared baby foods have increased tremendously in amount. In fact, the quantity of so-called ' baby-foods ' is equivalent to 36 lb. per year for all children under 3 years of age ! Over 60 per cent of the retail stores in the major cities are now equipped with frozen food cabinets.

Still another study reveals that on the average for the nation, only 25 to 30 cents of the consumer's dollar ever reaches the fruitgrower, the other 70 to 75 cents being spent for handling, packing, transportation and selling. And finally it has been shown that families of high income purchase substantially more fruits and vegetables *per capita* than families of low income—a matter of prime importance to you in England where income levels have been so drastically affected during the last decade.

It is small wonder that when these facts have been brought to the attention of the fruitgrower, some radical changes have been made in his thinking. It means that the fruitgrower has interested himself in carrying on some of the marketing operations, which have been so remunerative, such as pre-packaging, cold storage operations, and merchandizing, and that he is interested in producing a product which will compete successfully with other lines which have high market acceptability.

Obviously, many marketing problems originate in the field. The first consideration in this respect is an orderly supply of quality fruit. Many of the orchard practices that have been discussed are a result of this competitive pressure, particularly efficient insect and disease control, supplemental irrigation, blossom thinning, and foliar application of nutrients.

The second consideration is the delivery of a quality product to the consumer. Studies have shown that removal of field heat close to the place of production is imperative. The farm cold storage and large co-operative cold storages are the result. Hydro-cooling is receiving new attention, in which packed fruit is flooded with ice water as it comes in packages from the packing plant. Sour cherries are being placed in tanks of cold water at the farm and transported experimentally by tank truck to the processing plant, thus reducing both handling costs and fruit temperature at one swoop. Revolutionary thinking involves mechanical harvesters—even going so far as to think of tree defoliants which will leave the fruit for some sort of mechanical harvester.

Since the shortage of labour is the major problem on American farms, every conceivable gadget has been introduced to effect efficiency. Pneumatic pruners and hydraulic pruning and harvesting platforms have shown their worth. A strawberry planting machine will set 25 acres of strawberries in a day. In the pruning of black raspberries a vertical and a horizontal power mower has been devised which hacks the plants into control most brutally, but most efficiently. It will be interesting to see what progress the fruitgrower, the agricultural engineer, and the manufacturer will make in these directions in the next few years.

And finally, a word about the pattern of research in America. As has already been said, research is the critical search for knowledge. The word is often used to imply only professional or high-level scientific activity. One sometimes hears the expression ' pure research ' as though there were a form of research which is impure. The terms ' fundamental ' and ' basic ' are employed often with the connotation of superiority. Yet, fundamental research is simply research which is fundamental to something else, as trees are fundamental to lumber and lumber is fundamental to carpentry. What is fundamental research of to-day is the applied research of to-morrow only to be replaced in turn by something else fundamental.

It would seem that the real test of research is its *quality*. A fruitgrower who is diligently and self-critically seeking information is a useful research worker. There is no reason to exclude anyone from the field ; in fact, the more inclusive the term can be made, the better. Some of the most

worth-while leads and suggestions have come from the careful study and observations of amateurs. In the final test there are but two kinds of research—good research and bad research—the product of the long hard road requiring much time, or the easier and shorter road of mere superficial and often misleading observation.

Of course the emphasis in the programme of research may vary. There may be the emphasis on solving the little problem that arises day by day—what we call ' trouble-shooting ', and there may be the more carefully considered developmental type of research. Also there may be the closely directed research and there may be disinterested research, of which patience and free time are the essence.

Ordinarily, the support of research begins with the closely directed form. But the disinterested form, which may be at the moment less spectacular and often viewed with impatience, is the one which is being accepted more and more as the real ' pay off ' in significant achievement. As someone has said, it is more profitable just to dig than to dig specifically for a gold nugget. Urged on by love of digging, one may dig deeper and in a new vein. Practicality often is synonymous with short-sightedness. Horace Walpole coined the word ' serendipity ' for the gift of finding valuable or agreeable things not sought for. Dr. Irving Langmuir speaks of ' the art of profiting from unexpected occurrences '.

This does not mean, of course, that some degree of common sense should not prevail. If one is hunting elephants, he might more properly select Africa than London for his hunting grounds, yet an elephant escaping from the zoo might perhaps reward a hunter of big game, even in the streets of London. Or, to put it as someone else has done, ' Even a blind hog occasionally gets a chestnut '.

It would seem obvious, however, that research workers in horticulture should properly stay in the field of horticulture. In fact, it is doubtful if the research worker in horticulture should ever take his eye off the commodity, the individual, and the industry he serves. This limitation is hardly to be looked upon as confining. There is plenty of latitude.

Generally speaking, fruitgrowers in America are well aware of the value of research. But they are becoming increasingly aware of the dividends of the long range not closely directed type of research. More and more a publicly supported research laboratory may be asked to spend less of its time and energy on so-called ' practical ' problems, and be left to spend the larger percentage on the ' cast-your-bread-upon-the-waters ' type. No reflection is meant upon the abilities of highly trained research workers, but much of the developmental research can be carried on even better by advisers and practical fruitgrowers in the wide meaning of the word, which I prefer.

It goes without saying that this type of research does not mean laziness, disorder, and lack of imagination. Columbus may have discovered the New World by accident, but at least he was on the high seas looking for something. This should be the privilege or reward offered only to the best trained, the most industrious, the most imaginative, the most well-intentioned research worker and research institution. The returns of research are fabulous, even fantastic, as any will recognize who will look about for a moment and perhaps glance only at the contributions to horticulture from chemistry in 2,4-D and DDT, or that of Kidd and West in storage, or of virus-free stone fruit stocks. Research is the great opportunity for the modern investor.

And so we come to the end of our discussion. It has been a pleasant and satisfying experience to meet with you and to visit with you. Your hospitality may be equalled elsewhere, but never exceeded. May I speak for many of us in America to say that we never feel quite able to repay you for what you do for us when we visit you, but that we are always pleased when any of you come to see us, and provide us at least the chance to try. May many of you come often and stay long.

POMOLOGY

A DESCRIPTION AND CLASSIFICATION OF THE MALLING-MERTON AND MALLING XXV APPLE ROOTSTOCKS

By H. M. TYDEMAN

The following descriptions of the vegetative characters of the fifteen new Malling-Merton (MM.) apple rootstocks and of Malling XXV are provided primarily for recognition purposes. These rootstocks were bred by Mr. M. B. Crane of the John Innes Horticultural Institution and the author, and their behaviour in the nursery has been described by Garner (1953) and in the plantation by Preston (1953). Their parentage is given below.

The identification of apple varieties in the field, whether from fruits, foliage, or other characters, is a matter of much difficulty and can only be accomplished with confidence after considerable practice. It is rendered more difficult in the case of these new rootstocks by the fact that they all have one common parent, Northern Spy, while there are several in which both seed and pollen parent are the same. Consequently, many of them are very similar and it is frequently necessary to rely for identification on relatively inconspicuous features.

For roguing and certification, it is necessary to distinguish the new rootstocks, not only from each other, but also from those already in commercial use. Where the number of rootstocks to be identified is comparatively limited, it is possible, after practice, to recognize each by its general appearance without resorting to a detailed examination of its individual characters. Where it can be applied, this method is very satisfactory, but it becomes very difficult where more than a few rootstocks have to be distinguished, or where they differ from one another only in ways that are not readily seen on a superficial inspection. With the new Malling-Merton series, there are now more than thirty-five different varieties of apple rootstocks and, although the absence of sharply contrasted characters has made an analytical approach difficult, an attempt has been made to simplify the separation and identification of these by means of analytical keys.

Descriptions of the older rootstocks.

The original ' Paradise ' apple rootstocks, now known as Malling I to IX, were illustrated and described in detail by Hatton (1917). Garner (1946) published illustrations of Malling I, II, IV, V, VII, IX, XII, XIII, XVI and Crab C, accompanied by brief hints for their easy recognition. These are reproduced in Ministry of Agriculture Bulletin No. 135—' Fruit Tree Raising '. Maurer (1939) has given the most complete descriptions, in German, of Malling I to XVIII with copious illustrations.

Parentage of the new rootstocks.

The parents of the sixteen new rootstocks described in this paper were as follows :

MM.101.	Northern Spy	×	Malling I.
MM.102.	Northern Spy	×	Malling I.
MM.103.	Northern Spy	×	Ben Davis.
MM.104.	Malling II	×	Northern Spy.
MM.105.	Malling II	×	Northern Spy.
MM.106.	Northern Spy	×	Malling I.
MM.107.	Northern Spy	×	Malling XV.
MM.108.	Northern Spy	×	Malling XV.
MM.109.	Malling II	×	Northern Spy.
MM.110.	Northern Spy	×	Malling I.
MM.111.	Northern Spy	×	Merton 793 (Northern Spy × M.II).
MM.112.	Northern Spy	×	Winter Majetin.

MM.113.	Northern Spy × Malling XII.
MM.114.	Northern Spy × Malling XII.
MM.115.	Northern Spy × Ben Davis.
M.XXV.	Northern Spy × Malling II.

Characters studied.

The summer shoot characters of the fifteen Malling-Merton rootstocks and Malling XXV are described in Table I and those of the dormant winter shoots in Table II. Wherever possible, verbal descriptions have been supplemented by dimensions, expressed as the average of a large sample ; these are shown in Tables III and IV. The photographs provided should prove a valuable aid in identification (Figs. 1-25).

When examining apple shoots for the purposes of varietal recognition, and particularly the long annual growths from the stools commonly used for the identification of rootstocks in the nursery, it has to be remembered that there is not merely considerable variation from one shoot to another, but that there is also appreciable variation with regard to the expression of many characters as one passes from the base of the shoot to its tip. It is very desirable to examine several shoots of the same variety in order to obtain an average value for the character being studied and to confine the observations to the middle part of the shoot, where character expression is likely to be most typical.

Stools.

Where whole stools are available for examination, much may be learned from their general appearance and habit of growth. Varieties differ markedly from one another in the number of shoots they produce when stooled ; whether the individual shoots are erect or whether they tend to spread ; whether they are clean and straight or with many thorns or side branches.

Shoots.

Differences in the stoutness and flexibility of the shoots are useful. Certain rootstocks, such as MM.108, are characterized by short, stocky, stiff shoots with short internodes, while others, such as MM.115, have long, rather whippy, flexible shoots with long internodes and a rather loose, straggling habit of growth. The flexibility of the shoots can best be determined by exerting slight pressure with the finger and thumb towards the middle of the shoot. Those described as stiff will bend very little under such pressure and will fracture if bent more than slightly. Flexible shoots, on the other hand, can often be bent into a complete loop without sustaining damage. This character of relative flexibility is the basis of the classification given in the keys at the end of this paper, but it must be remembered that, like practically all other characters in the apple, it is not discontinuous and some practice may be necessary before the separation can be made with confidence.

Bark.

Most apple shoots are covered to a greater or lesser extent by greyish or whitish pubescence which varies in amount from one variety to another. This pubescence must be removed before the true colour of the bark can be seen. The typical colour can only be seen in the centre of the shoot which is frequently green towards its base, where light has been excluded, and imperfectly ripened towards its tip. The shoots of some varieties have a slightly burnished appearance, comparable to the sheen on pewter. This is a characteristic feature of the bark of M.IX and can also be seen on several of the rootstocks here described. The bark is often marked in various ways by ridgings, striations and grainings, all of which are useful in helping to distinguish varieties.

Lenticels.

Much useful assistance in identification may be obtained from the lenticels. The presence of pubescence, particularly if it is at all profuse, will tend to obscure them, and this should be removed before they are studied in detail. The lenticels may differ in number, size, shape, and colour, and, although there is much variation from one shoot to another within each individual variety, the differences between varieties are considerably greater. It is possible to classify the rootstocks into those with few and those with numerous lenticels and this has been made one of the divisions in the Keys. Size and shape are much more difficult to define with accuracy since they may vary widely upon the same shoot but there are certain stocks, such as MM.109, that have fairly large lenticels. Variations in colour are not common but, where they exist, as in MM.113, they afford a useful means of differentiation. Usually the lenticels are quite level with the surface of the shoot but, in one or

TABLE I.

SUMMER CHARACTERS.

	MM.101	MM.102	MM.103	MM.104	MM.105	MM.106	MM.107	MM.108	MM.109	MM.110	MM.111	MM.112	MM.113	MM.114	MM.115	M.XXV
General habit																
Growth	Vigorous; stiff, erect, slightly zigzagged shoots.	Vigorous; **stiff, erect,** somewhat zigzagged shoots.	Vigorous; rather spreading, flexible, somewhat zigzagged shoots.	Vigorous; rather spreading, stiff shoots.	Not very vigorous; stiff, somewhat zigzagged shoots.	Vigorous; somewhat spreading, stiff, stoutish shoots.	Vigorous; erect, stout, whippy shoots with short internodes.	Weak; stiff, wiry shoots with short internodes.	Not very vigorous; stiff, erect shoots.	Vigorous; spreading, stiff zigzagged shoots.	Vigorous; erect, stiff, stout, somewhat zigzagged shoots.	Vigorous; spreading, stoutish, flexible shoots.	Very vigorous; spreading, fairly flexible shoots.	Fairly vigorous; erect, flexible shoots, short internodes.	Very vigorous; stout, flexible shoots.	Not very vigorous; erect, stiff, rather stocky shoots.
Feathering	Slight.	Slight.	Very little.	Slight.	Little	Little.	Some.	Little.	Slight.	Some.	Some.	Little.	Slight.	Slight.	Little.	Considerable.
Number of shoots on stools	Fairly prolific.	Fairly prolific.	Fairly prolific.	Fairly prolific.	Fairly prolific.	Prolific.	Not very many.	Few.	Fairly prolific	Prolific.	Fairly prolific	Prolific.	Very prolific.	Fairly prolific.	Very prolific.	Fairly prolific.
Wood.																
Colour	Deep reddish brown.	Dull chocolate brown.	Rather dull reddish brown.	Deep reddish brown.	Deep chocolate brown **with faint pewter-like sheen.**	Dark chocolate brown.	Deep purplish brown	Deep greyish brown **with faint pewter-like sheen.**	Dull purplish brown.	Deep chocolate brown.	Dull purple brown with distinct pewter-like sheen.	Deep chocolate brown.	Smoky greyish brown.	Dull reddish brown.	Deep purplish brown.	Deep chocolate brown with slight sheen.
Hairiness	Covered with thick whitish pubescence.	Covered with thin whitish pubescence.	Covered with thin whitish pubescence.	Covered with thin whitish pubescence.	Covered with whitish pubescence.	**Covered with fairly profuse whitish pubescence.**	**Covered with fairly profuse whitish pubescence.**	Covered with slight whitish pubescence.	Covered with thin whitish pubescence.	Covered with thin whitish pubescence.	Covered with somewhat profuse whitish pubescence.	Covered with fairly thick whitish pubescence.	Covered with slight whitish pubescence.	Covered with fine whitish pubescence.	Covered with fairly profuse whitish pubescence.	Covered with fine whitish pubescence.
Texture	Fairly rough, striated.	Covered with fine grainings, fairly smooth.	Striated.	Distinctly ridged. Finely grained.	Covered with faint streaks	Distinctly finely grained.	Coarse, finely striated.	Faintly striated with lighter brown.	Faintly striated.	Striated and distinctly ridged.	Faintly grained.	Faintly striated and slightly ridged along the bundles	Striated, distinctly ridged	Distinctly striated, often with pronounced ridge.	Faintly striated.	Distinctly striated, finely grained.
Other features	—	—	Shoots slightly flattened, swollen at the nodes.			Somewhat swollen at the nodes.					**Somewhat swollen at the nodes.**				Much swollen at the nodes.	
Lenticels.																
Number	Numerous.	Very numerous.	Fairly numerous.	Very numerous.	Fairly numerous.	Fairly numerous.	Fairly numerous.	Few.	Fairly numerous	Very numerous.	Fairly numerous	Fairly numerous.	Numerous.	Numerous.	Fairly numerous.	Fairly numerous.
Conspicuousness	Conspicuous, **slightly raised,** largish.	Fairly conspicuous, small.	Fairly conspicuous, largish.	Large, conspicuous.	Fairly large, conspicuous.	Not very conspicuous, small.	Conspicuous, small.	Inconspicuous, variable.	Conspicuous, rather large.	Conspicuous, slightly raised, large.	Inconspicuous, small	Inconspicuous, small	Inconspicuous, small.	Conspicuous, small.	Conspicuous, medium size.	Conspicuous, small.
Shape and Colour	Elliptical, **deep brownish orange.**	Variable roundish, dull brownish yellow	Oval, bright brownish yellow.	Oval, dull brownish yellow.	Rounded, brownish yellow.	Oval, pale brownish yellow	Oval, deep brownish yellow.	Oval, deep brownish yellow.	Variable oval, deep brownish yellow	Oval, deep brownish yellow.	Oval, deep brownish yellow	Oval, deep brownish yellow.	Oval, deep brownish orange.	Circular, deep brownish yellow, almost orange.	Oval, dull brownish yellow.	Oval, deep brownish yellow.
Leaves.																
Size	Medium.	Medium.	Medium.	Medium.	Medium.	Fairly large	Medium.	Small.	Smallish.	Medium	Medium.	Large.	Largish.	Smallish.	Large.	Small.
Shape	Medium ovate.	Medium oval.	Medium oval, almost rectangular.	Oval.	Medium oval.	Medium ovate.	Medium oval.	Broadly oval.	Narrowly ovate.	Broadly oval	Medium to broadly oval	Medium oval.	Medium oval	Broadly ovate.	Obovate to oblong-ovate.	Medium ovate.
Base	Rounded, lamina often extending down the petiole.	Rounded, lamina slightly extending down the petiole.	Broadly wedge shaped.	Rounded.	**Broadly wedge-shaped, often unequal.**	Rounded, often unequal	Flattish rounded.	Flat.	Broadly wedge-shaped.	Flattish	Broadly wedge-shaped, often unequal.	Rounded.	Rounded.	Rounded.	Broadly wedge-shaped.	Rounded.
Apex	Gradually acuminate, tips drawn out, downturned.	Gradually acuminate, **downturned, twisted.**	Abruptly acuminate, much drawn out, twisted.	Abruptly acuminate, somewhat drawn out	Gradually acuminate **tips much drawn out, very acute.**	Gradually and slightly acuminate, downturned, twisted	Abruptly acuminate, twisted, downturned	Abruptly acuminate	Gradually acuminate, twisted	Abruptly acuminate	Gradually and shortly acuminate.	**Abruptly acuminate, downturned and twisted.**	Abruptly acuminate.	Gradually shortly acuminate, downturned.	Abruptly acuminate, often downturned and twisted.	Gradually acuminate, slightly upturned.
Serrations	Finely and acutely serrate, slightly turned over.	Finely and acutely serrate, **downturned, often tipped brown.**	Fairly acutely serrate, flat.	Rather coarsely serrate	Very finely serrate, tips rather obtuse.	Finely and rather obtusely serrate.	Finely serrate.	Finely to medium serrate.	**Acutely serrate, deeply incised.**	**Finely and acutely serrate, pointing downwards.**	**Coarsely serrate, tipped with red, often faintly lobed.**	Coarsely and irregularly serrate, slightly downturned.	**Finely rounded, almost crenate.**	Coarsely and obtusely serrate	Coarsely and acutely serrate	Finely serrate.
Surface	Very shallowly upfolded	Older leaves flat, younger leaves often slightly upfolded.	**Flat, often convex towards the base.**	Shallowly upfolded, convex.	Flat.	Flat, very slightly upfolded.	Flat	**Upfolded.**	Shallowly upcupped.	Flat or slightly convex, rather crinkled.	Upcupped.	Flat, often slightly convex, much crinkled.	Upcupped.	Shallowly upfolded.	Shallowly upcupped.	**Usually flat, often convex, much crinkled.**
Margin	Slightly undulating.	Slightly undulating.	Slightly undulating.	Upturned, undulating	Flat, very slightly undulating.	Undulating	Slightly raised, undulating	Upturned and undulating.	**Raised and frilled in short waves.**	Slightly downturned, distinctly waved	Raised and wavy.	Very undulating.	Undulating.	Slightly raised and undulating.	**Upturned, shortly waved, giving a ragged appearance.**	Slightly raised, broadly undulating.
Pose in relation to stem	Very slightly upturned.	Generally horizontal.	Horizontal or slightly upturned.	Horizontal, slightly upturned.	Somewhat upturned.	Horizontal, younger leaves upfolded.	Horizontal	Horizontal.	Upturned, curved over.	Slightly upturned	Horizontal	Slightly downturned.	Horizontal.	Downturned, curved over.	Horizontal.	Horizontal, slightly downturned.
Colour	Upper surface rather dull green.	Deep green.	Rather dull deep green.	Deep green, fairly glossy	Dull olive green, not very glossy.	Dark green, fairly glossy.	**Deep green, very glossy.**	Deep green not very glossy, younger leaves bright green.	Dull deep green with a matt surface.	Deep green, younger leaves bright yellowish green.	Deep green, surface dull	Deep green.	Dull green, younger **leaves bright grass green**	Dark green.	Deep green, rather dull.	Deep green, sea-green when seen in the mass.
Hairiness on under surface	Slightly woolly.	Covered with soft woolly hairs.	Covered with soft woolly hairs.	Covered with soft woolly hairs	Few short pale hairs.	Covered with fine woolly hairs.	Covered with pale woolly hairs	Little, slightly shiny.	Densely covered with short woolly hairs	Few hairs	Some short, soft, woolly hairs	Fairly hairy.	Only slightly hairy.	Some short woolly hairs	Covered with short woolly hairs.	Some short woolly hairs.
Texture	Slightly rough, rather papery.	Decidedly rugose, crisp and papery.	Smooth and papery.	Slightly rugose, crisp	Crisp and papery.	Somewhat rugose, crisp and papery.	Fairly thin and soft.	Stiff, crisp and slightly rugose.	Crisp and papery.	Thin, crisp, rather rugose	Crisp and papery.	Thin and papery.	Soft and flannelly.	Smooth and rather soft	Thick and flannelly.	Crisp, papery, somewhat rugose.
Colour of tips of shoots	Bright yellowish green with brownish margins.	Pale green with coppery coloured edges.	Yellowish green bordered with brownish red.	Pale green with slight bronzing.	Slightly bronzed.	Pale yellowish green, often bronzed round edges.	Pale whitish green, edged with deep red.	Slightly bronzed, even on under surface.	Pale green, often much bronzed.	Slightly bronzed.	Whitish green	Silvery.	Pale green edged with faint purple.	Light green with slight reddish tinge	Distinctly bronzed.	Pale silvery green.
Leaf stalk.																
Shape	Slender, deeply channelled.	Stout, deeply channelled.	Slender, channelled.	Slender, channelled.	Slender, very shallowly channelled.	Slender, channelled.	Slender, shallowly channelled	Slender, shallowly channelled	Shallowly channelled	Slender, channelled.	Slender, channelled.	Slender, channelled.	Slender, channelled.	Very stout, deeply channelled, **distinctly kinked near base.**	Slender, channelled.	Slender, channelled.
Length	Short.	Medium.	Very long.	Short.	Short.	Long.	Short.	Short.	Long.	Short.	Long.	Short.	Short.	Medium.	Fairly long.	Fairly long.
Colour	Slightly tinged dull red.	Tinged deep pink extending to lamina underneath.	Tinged dull red, very pubescent.	**Tinged brilliant wine red. Buds in axils tinged deep red.**	Tinged deep wine red above and below.	Tinged dull red.	Slightly tinged dull red	Slightly tinged dull red at base.	Much tinged deep wine red extending up the lamina.	Slightly tinged red at base.	Slightly tinged dull red.	Slightly tinged dull red at base.	Slightly tinged dull red.	Slightly tinged dull red.	Mainly green with red blotches.	Slightly tinged red.
Pose	Upturned.	Outturned.	Outturned.	**Much** outturned.	Upturned.	Much outturned.	Upturned.	Upturned.	Upturned.	Upturned.	Upturned.	Outturned.	Upturned.	Outturned.	Outturned.	Upturned.
Stipules.																
Size	Long, more than half as long as petiole.	Fairly large, almost as long as petiole.	Small.	Very small.	Small.	Fairly large, often almost as long as petiole.	Fairly large, almost as long as petiole.	Usually smallish to medium.	Small.	Large.	Usually smallish.	Fairly large.	Medium, less than half as long as petiole.	Fairly small.	Small.	Very small.
Margin	Serrate.	Faintly serrate.	Irregularly and faintly serrate.	Entire, fringed with short hairs.	Finely serrate.	Faintly serrate	Entire.	Entire.	Entire, fringed with hairs.	Distinctly serrate.	Entire, fringed with short hairs.	Slightly serrate.	Entire, fringed with hairs.	Entire, slightly fringed with hairs.	Slightly serrate.	Faintly serrate.
Shape	Lanceolate.	Broadly lanceolate, distinctly stalked.	Crescent-shaped.	Crescent-shaped.	Lanceolate.	Irregularly broadly lanceolate, short stalked.	Broadly crescent-shaped, distinctly stalked.	Narrowly lanceolate, short stalked.	Narrowly crescent-shaped, short stalked, often tinged red.	Elliptical.	Crescent-shaped.	Broadly lanceolate.	Lanceolate, short stalked, tinged red.	Narrowly lanceolate, short stalked, tinged red.	Crescent-shaped.	Lanceolate, short stalked.
Pose	Rather upturned, close together.	Horizontal, close to petioles.	Horizontal and spreading.	Spreading, at right angles to petiole.	Spreading.	Fairly spreading.	Slightly upturned, almost spreading.	Horizontal, spreading.	Horizontal.	Horizontal, spreading.	Horizontal, spreading.	Horizontal, spreading.	Horizontal, spreading.	Horizontal, held close to petioles.	Fairly spreading.	Spreading.
Season of leaf-break.	Early.	Late.	Midseason.	Midseason.	Early.	Midseason.	Fairly late.	Late.	Early.	Early.	Late.	Late.	Late.	Midseason.	Midseason.	Early.
Time of defoliation.	Early.	Intermediate.	Intermediate.	Fairly late.	Early.	Fairly late.	Very late.	Late.	Early.	Intermediate.	Fairly early.	Very late.	Late.	Fairly late.	Fairly late.	Fairly early.
Colour of foliage in autumn.	Dull green changing to yellow with coppery red patches.	Dull green turning to bronzy yellow.	Deep wine red.	Pale green changing to dull yellow.	Bright coppery red.	Dull greyish green, changing to dull khaki yellow.	Deep glossy green.	Deep green with whitish tips changing to yellow.	Dull khaki yellow, tips of shoots green.	Dull greyish green.	Dull green mottled with pale green, changing to yellowish khaki.	Deep bluish green.	Deep bluish green with whitish tips.	Dull greyish green, changing to yellow at base.	Changing to deep coppery red.	Dull coppery to khaki yellow, tips green.

NOTE. Characters printed in **heavy type** will be found most useful for identification purposes.

TABLE II.

WINTER CHARACTERS.

	MM.101	MM.102	MM.103	MM.104	MM.105	MM.106	MM.107	MM.108	MM.109	MM.110	MM.111	MM.112	MM.113	MM.114	MM.115	M.XXV
General habit.																
Strength of growth	Vigorous.	Vigorous.	Vigorous.	Vigorous.	Intermediate.	Vigorous.	Vigorous.	Rather weak.	Intermediate.	Vigorous.	Vigorous.	Vigorous.	Very vigorous.	Fairly vigorous.	Very vigorous.	Not very vigorous.
Habit of growth	Fairly erect.	Erect.	Inclined to be spreading.	Rather spreading.	Fairly erect.	Slightly spreading.	Very erect.	Erect.	Erect.	Very spreading.	Fairly erect.	Rather spreading.	Spreading.	Erect.	Rather spreading.	Fairly erect.
Number of laterals	Very few.	Very few.	Very few.	Some.	Few.	Few.	Some.	Few.	Few.	Many.	Some.	Few.	Few.	Few.	Few.	Usually many.
Wood.																
Stoutness	Fairly stout.	Fairly stout.	Rather slender.	Rather slender.	Fairly stout.	Fairly stout.	Fairly stout.	Stoutish and stocky.	Fairly stout.	Fairly stout.	Fairly stout.	Fairly stout.	Not very stout.	Fairly stout.	Fairly stout.	Fairly stocky.
Flexibility	Stiff.	Rather stiff.	Very flexible.	Stiff.	Rather stiff.	Stiff.	Fairly flexible.	Stiff.	Very stiff.	Very stiff.	Rather stiff.	Very flexible.	Flexible.	Very flexible.	Flexible.	Quite stiff.
Internodes	About medium length somewhat zigzagged, nodes much swollen.	About medium length, nodes somewhat swollen.	About medium length zigzagged, nodes slightly swollen.	Short, distinctly zigzagged.	Rather short and slightly zigzagged.	Short, somewhat zigzagged, rather swollen at node.	Short, nodes very even.	Rather short and straight.	Medium length.	Fairly long.	Quite short, considerably swollen at node.	Medium length, slightly zigzagged	Medium length, somewhat swollen at node	Rather short.	Fairly long, considerably swollen at node.	Rather short.
Colour	Deep purple brown.	Bright reddish brown.	Deep reddish brown.	Dark reddish brown.	Dull reddish brown with bright metallic lustre.	Dull chocolate brown	Pale purplish brown with slight metallic lustre.	Greyish brown with slight sheen.	Deep purple brown.	Bright chocolate brown with large green patches.	Deep purple brown with distinct metallic lustre.	Dark reddish brown with greenish patches.	Deep greyish brown.	Deep reddish brown.	Dark purple brown with green patches.	Deep chocolate brown.
Hairiness	Covered with fairly profuse whitish pubescence.	Covered with slight whitish pubescence.	Covered with faint whitish pubescence.	Covered with slight whitish pubescence.	Covered with considerable whitish pubescence.	Covered with thick whitish pubescence.	Covered with very slight whitish pubescence.	Covered with slight whitish pubescence.	Some fine whitish pubescence.	Slight pubescence.	Covered with fine whitish pubescence.	Very little pubescence.	Covered with fine whitish pubescence.	Covered with slight whitish pubescence.	Covered with slight whitish pubescence.	Covered with faint whitish pubescence.
Texture	Slightly ridged, rather rough.	Slightly grained and ridged.	Distinctly striated and grained, with long ridges.	Ridged and finely grained.	Finely grained, fairly smooth.	Finely grained slightly ridged.	Distinctly striated, ridged.	Fairly smooth.	Slightly rough to touch.	Distinctly longitudinally ridged, somewhat rough.	Fairly smooth.	Finely ridged with longitudinal striations.	Striated with distinct longitudinal ridges.	Distinctly striated and ridged.	Faintly striated, slightly ridged.	Distinctly striated.
Lenticels.																
Number	Very numerous.	Very numerous.	Fairly numerous.	Very numerous.	Fairly numerous.	Fairly numerous.	Fairly numerous.	Few.	Fairly numerous.	Very numerous.	Fairly numerous.	Fairly numerous.	Numerous.	Numerous.	Fairly numerous.	Fairly numerous.
Distribution	Most numerous towards base of shoot.	Clustered, especially towards base of shoot.	Rather more numerous towards base of shoot.	Most numerous towards base of shoot.	Scattered all up shoot.	Scattered.	More numerous towards base of shoot.	Most numerous towards base of shoot.	Most numerous towards base of shoot.	Most numerous towards base of shoot.	Most numerous towards base of shoot.	Most numerous towards base of shoot.	Scattered.	Fairly evenly distributed.	Most numerous towards base of shoot.	Most numerous towards base of shoot.
Size	Fairly large and conspicuous, slightly raised.	Medium.	Fairly large and conspicuous.	Large.	Fairly large, slightly raised.	Small, indistinct.	Small.	Often fairly large.	Fairly large, slightly raised.	Fairly large, slightly raised.	Smallish.	Small.	Small, indistinct.	Smallish, fairly distinct.	Smallish but conspicuous.	Small but distinct.
Colour	Deep orange brown.	Deep brownish yellow.	Brownish yellow.	Brownish yellow.	Brownish yellow.	Brownish yellow.	Deep brownish yellow.	Pale brownish yellow.	Pale brownish yellow.	Pale brownish yellow.	Brownish yellow.	Pale brownish yellow.	Deep brownish orange	Brownish yellow, often almost orange.	Pale brownish yellow.	Brownish yellow.
Shape	Rounded.	Rounded.	Oval.	Oval.	Rounded.	Oval.	Oval.	Oval.	Variable, oval.	Oval.	Oval.	Oval.	Oval.	Rounded.	Oval.	Oval.
Buds.																
Size	Small.	Good medium size.	Small.	Medium.	Medium.	Small.	Small.	Small.	Medium	Rather small.	Good medium size.	Small.	Smallish.	Small.	Very small.	Fairly small.
Shape	Flattish-triangular with rounded apex.	Semicircular to broadly triangular, fairly plump.	Semicircular with rounded apex.	Semicircular, rather flat topped, plump, rounded.	Rather triangular and somewhat pointed.	Flattish-triangular with obtuse rounded apex.	Oval-triangular with flattish apex.	Broadly triangular with obtuse, rounded apex.	Oval-triangular with fairly acute apex.	Semicircular-triangular with rounded apex.	Triangular, about as long as broad, apex pointed.	Short and broad, oval, fairly pointed.	Short and broad, triangular with rounded, obtuse apex.	Semicircular-triangular with rounded apex.	Triangular-oval somewhat pointed.	Plump, oval-triangular with rounded apex.
Compactness	Fairly compact.	Slightly ragged at tips.	Fairly compact.	Fairly compact.	Compact.	Fairly compact.	Compact.	Compact.	Compactly wrapped.	Compactly wrapped.	Often rather ragged.	Compactly wrapped.	Compactly wrapped.	Compactly wrapped.	Often slightly ragged.	Fairly compactly wrapped.
Colour	Pale ashen grey with greyish red patches.	Ashen grey with flecks of red.	Pale ashen grey with patches of dull red.	Bright red much flecked with ashen grey.	Deep, clear red with faint sooty patches.	Ashen grey.	Dull sooty red with flecks of pale ashen grey.	Dull brownish red flecked with pale ashen grey.	Bright brownish red with much ashen grey.	Pale ashen grey with sooty red patches.	Ashen grey.	Pale ashen grey	Pale ashen grey with flecks of bright red.	Smoky grey with flecks of deep red.	Pale ashen grey.	Deep smoky red with greyish streaks.
Hairiness	Some fine silvery hairs.	Some fine silvery hairs.	Some fine silvery hairs.	Some fine silvery hairs.	Some fine silvery hairs.	Covered with short silvery hairs.	Some fine silvery hairs.	Few short silvery hairs.	Some pale silvery hairs.	Covered with fine silvery hairs.	Covered with fine silvery hairs.	Covered with fine silvery hairs.	Some fine silvery hairs.	Some short silvery hairs.	Some fine silvery hairs.	Some fine silvery hairs.
Pose	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Variable, often slightly outturned.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Generally closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.	Closely adpressed to shoot.
Base	Rather extended and clawed.	Rather extended and clawed, often quite sharp.	Somewhat extended and clawed.	Somewhat extended and clawed.	Very little extended.	Rather extended and clawed.	Litte extended.	Very little extended.	Considerably extended and clawed.	Very little extended.	Very considerably extended and clawed.	Only very slightly extended, ridged and flattened below.	Somewhat extended and clawed.	Only very slightly extended.	Considerably extended and clawed.	Only very slightly extended.

Table III.

DIMENSIONS OF VARIOUS FOLIAGE CHARACTERS.

(Averages of fifty observations)

	Leaf Blade.						Leaf Stalk.		Stipules.			
	Length. mm.	Breadth. mm.	Breadth expressed as a % of length.	Length of leaf tip. mm.	Expressed as a % of length of leaf blade.	Number of serrations.	Length. mm.	Expressed as a % of length of leaf blade.	Length. mm.	Expressed as a % of length of leaf stalk.	Breadth. mm.	Expressed as a % of length of stipule.
MM.101 ..	70	52	74	8	11	76	16	23	8	50	2	25
MM.102 ..	75	54	72	7	9	83	23	31	15	65	3	20
MM.103 ..	73	53	73	10	14	84	29	40	11	38	2	18
MM.104 ..	75	48	64	8	11	77	21	28	7	33	1	14
MM.105 ..	73	50	68	10	14	57	18	25	8	44	2	22
MM.106 ...	83	59	71	10	12	94	27	33	16	59	3	19
MM.107 ...	75	52	69	10	13	64	17	23	12	71	3	25
MM.108 ..	62	48	77	8	13	51	15	24	7	47	1	14
MM.109 ..	62	41	66	9	15	83	21	34	8	38	1	13
MM.110 ..	75	57	76	7	9	90	16	21	12	75	4	33
MM.111 ..	69	51	74	5	7	57	24	35	8	33	1	13
MM.112 ..	84	60	71	8	10	87	16	19	8	50	2	25
MM.113 ..	81	56	69	9	11	70	19	23	9	47	2	22
MM.114 ..	64	57	89	5	8	81	18	28	8	44	1	13
MM.115 ..	82	62	76	9	11	79	22	[illegible]	9	41	2	22
M.I	80	59	74	9	11	64	14	18	15	107	3	20
M.II ..	75	51	68	9	12	57	16	21	4	25	1	25
M.IV ..	65	49	75	7	11	75	19	29	4	21	1	25
M.VII ..	65	51	78	7	11	46	18	28	5	28	1	20
M.IX ..	80	54	68	11	14	87	16	20	8	50	2	25
M.XII ..	69	49	71	8	12	66	17	25	8	47	2	25
M.XV ..	63	51	81	8	13	51	14	22	10	71	2	20
M.XVI ..	72	47	65	8	11	38	13	18	8	62	1	13
M.XXV ..	59	39	66	8	14	81	17	29	5	29	1	20
Northern Spy ..	88	62	70	10	11	77	24	27	12	50	3	25
Ivory's Double Vigour	94	68	72	12	13	112	19	20	15	79	5	33

Table IV.

DIMENSIONS OF CERTAIN CHARACTERS ASSOCIATED WITH THE SHOOTS DURING DORMANCY.

(Averages of fifty observations)

	Diameter of Shoots.					Dimensions of Buds.				Length of internode. mm.	Lenticels—number per centimetre of shoot.
	Between the buds. mm.	Across the buds. mm.	Percentage increase.	Through the buds. mm.	Percentage increase.	Length. (*L*) mm.	Breadth. (*B*) mm.	Length expressed as a % of breadth.	Size. ($\frac{1}{2}LB$) sq.mm.		
MM.101 ..	8	9	13	10	25	4	4	100	8	21	20
MM.102 ..	8	9	13	10	25	4	4	100	8	22	22
MM.103 ..	7	8	14	9	29	3	3	100	5	25	13
MM.104 ..	6	7	17	8	33	4	4	100	8	20	19
MM.105 ..	8	9	13	10	25	4	4	100	8	15	13
MM.106 ..	7	9	29	9	29	3	4	75	6	21	15
MM.107 ..	6	6	0	7	17	3	4	75	6	15	11
MM.108 ..	6	7	17	7	17	3	3	100	5	14	5
MM.109 ..	7	8	14	10	43	4	4	100	8	23	12
MM.110 ..	8	9	13	10	25	4	4	100	8	26	19
MM.111 ..	6	8	33	8	33	4	4	100	8	20	16
MM.112 ..	7	8	14	9	29	3	4	75	6	24	12
MM.113 ..	6	7	17	8	33	3	4	75	6	24	17
MM.114 ..	7	8	14	9	29	3	4	75	6	20	18
MM.115 ..	7	8	14	10	43	2	3	67	3	28	11
M.I ..	6	6	0	7	17	4	4	100	8	27	9
M.II ..	7	7	0	8	14	4	4	100	8	17	18
M.IV ..	6	7	17	7	17	3	3	100	5	18	7
M.VII ..	6	6	0	7	17	2	3	67	3	21	10
M.IX ..	6	6	0	7	17	3	3	100	5	21	4
M.XII ..	8	8	0	9	13	3	4	75	6	19	13
M.XV ..	6	6	0	7	17	3	4	75	6	15	7
M.XVI ..	8	8	0	9	13	4	4	100	8	20	7
M.XXV ..	7	7	0	8	14	3	4	75	6	14	11
Northern Spy ..	9	10	11	11	22	3	4	75	6	29	16
Ivory's Double Vigour	10	11	10	12	20	3	5	60	8	27	17

two stocks, they are distinctly raised and may be felt as tiny bumps if the finger is passed gently up and down the surface of the shoot.

Buds.

The characters of the buds can only be studied satisfactorily during the dormant season. Of the stocks dealt with here, one, MM.104, may be distinguished in summer by the red coloration of its buds if the leaf petioles are pulled away. In winter, the buds of the various rootstocks vary in size, shape, colour, the compactness with which the buds scales are folded and their pose in relation to the axis of the shoot. The bark immediately beneath the bud is frequently clawed into distinct folds, or the whole area of the node may be considerably swollen. In Northern Spy and MM.111 the bud bases are so much extended that, in summer, they may be felt as distinct knobs on passing the finger along the underside of the petiole towards its base.

Leaves.

In using the leaves as a means of identification great care must be taken to select only those from the middle part of the shoot at a time when they are fully grown. Those towards the top of the growing shoot will be found to be narrower and more upturned and those towards the base broader and more drooping than is typical for the variety as a whole. Generally speaking, such characters as leaf shape and petiole length are not easy to assess accurately unless reference is constantly made to some standard. For this purpose, the data given in Table III may be found to be of assistance. The length and shape of the leaf tip, the folding of the leaf surface, and the pose of the leaf in relation to the petiole, and also to the axis of the shoot, all show variation from one variety to another. The leaves of MM.102 are distinctive in having the serrations downturned so that they can be felt as minute sharp points when the finger is passed round below the edge of the leaf. The very fine, acute serrations and frilled leaf margins of MM.109 and the rounded, almost crenate, teeth of MM.113 are examples of conspicuous differences between varieties. Leaf colour, hairiness, and texture are less reliable as distinguishing characters, the first, in particular, showing considerable positional variation, although the characteristic sea-green appearance of the massed foliage of M.XXV may afford a useful clue to its identity. The length of the leaf stalk is best assessed in relation to that of the leaf blade. Leaves of MM.103, MM.109, and MM.111 have notably long leaf stalks while those of MM.112 are short, but the differences are not always very obvious although they show very clearly in Table III. The petioles are always tinged with red particularly along the back but this character shows considerable seasonal fluctuation and can only rarely be relied upon as an aid in identification, although MM.104 can be recognized by the exceptionally vivid and extensive coloration of its leaf petioles. The pose of the leaf stalk in relation to the axis of the shoot is a very useful character for recognition purposes and has been used in the Key to separate varieties. It is best studied at the height of the growing season and near the middle of the shoot. The pose of the leaf blade in relation to the petiole or the shoot should be disregarded and only the angle which the leaf stalk makes with the shoot taken into account. The stalk may be very erect, forming a very narrow angle of 30 to 40 degrees or less from the vertical, or it may be much outturned, forming a wide angle of 70 to 80 degrees. For a pictorial example, Figure 5 should be compared with Figure 4.

Stipules.

These are the small leaf-like outgrowths from the base of the leaf stalk. They may vary in size, shape, and pose, and may have stalks or be almost without. The margins may be serrated or smooth. All these characters show differences from one variety to another, but stipule size is the most constant and useful, and can be most conveniently gauged in relation to that of the leaf stalk.

Classification of the rootstocks.

Maurer (1939) has attempted a classification of the eighteen Malling types described in his book, based on the colour of the wood and certain other vegetative characters. In attempting the classification of the thirty-five varieties shown in the Keys, the writer has not followed the lines of Maurer's work but has based his keys upon those characters which, in his experience, have proved the most distinctive and uniform. Care has been taken to use only characters likely to be available on detached shoots at midsummer and midwinter respectively. Considerable additional assistance might be afforded by the time of leaf-break or leaf-fall, or the colour of the spring or autumn foliage but these will not always be available on a short visit of inspection.

Keys for identification.

The following keys have been prepared as an aid to identification :

FROM SUMMER CHARACTERS

I. SHOOTS STIFF TO VERY STIFF, USUALLY STOUT AND ERECT ON STOOLS.

A. Lenticels very numerous, numerous, or fairly numerous.

1. Stipules large, more than half as long as the petioles.

a. *Petioles very erect forming narrow angle with shoot.*

Rather rough shoots with brownish orange, raised lenticels **MM.101**
Leaves flat or convex, slightly crinkled **MM.110**
Margins of leaves very frilled .. .. **M.X**
Leaves upfolded and upturned, petioles knobbed at the base .. .. **Northern Spy**

b. *Petioles outturned forming wide angle with shoot.*

Edges of the serrations downturned and often tinged brownish red **MM.102**
Shoots swollen at the nodes with profuse pubescence **MM.106**
Light greenish brown shoots with much grey pubescence .. .. .. **M.VI**
Leaves large, much curved over and downturned .. .. .. **Ivory's Double Vigour**

2. Stipules small, linear-lanceolate or crescent-shaped.

a. *Petioles very erect forming narrow angle with shoot.*

Slightly upturned leaves with wedge-shaped bases **MM.105**
Margins of leaves raised and frilled **MM.109**
Leaves with coarsely and acutely serrate teeth, often tipped with red .. **MM.111**
Flat, horizontal leaves with fine, rounded serrations and wedge-shaped bases **M.II**
Small, crinkled, often convex leaves .. .. **M.XXV**

b. *Petioles outturned forming wide angle with shoot.*

Backs of petioles tinged brilliant wine red extending up the midribs, buds tinged deep red **MM.104**
Bright reddish chocolate wood and deep orange lenticels .. .. .. **M.XII**

B. Lenticels few or very few.

1. Stipules large, more than half as long as petioles.

a. *Petioles very erect forming narrow angle with shoot.*

Leaf margins irregularly serrate, often almost entire .. .. .. **M.XVI**

2. Stipules small, linear-lanceolate or crescent-shaped.

a. *Petioles very erect forming narrow angle with shoot.*

Broad, upfolded leaves, shoots with short internodes **MM.108**

II. SHOOTS FAIRLY FLEXIBLE, OFTEN SLENDER AND SPREADING ON STOOLS.

A. Lenticels very numerous, numerous, or fairly numerous.

1. Stipules large, more than half as long as petioles.

a. *Petioles very erect forming narrow angle with shoot.*

Stout, zigzagged shoots with short internodes **MM.107**
Distinctly ridged and zigzagged, greyish brown shoots .. .. .. **M.XI**
Older wood blackish with conspicuous whitish lenticels and very upturned leaves .. .. **M.XIII**
Leaf margins acutely and coarsely triserrate .. .. **Crab C**

b. *Petioles outturned forming wide angle with shoot.*

Flat or convex leaves with downturned and twisted tips **MM.112**
Zigzagged shoots with broad leaves, held almost horizontally .. .. **M.I**

2. Stipules small, linear-lanceolate or crescent-shaped.

a. *Petioles very erect forming narrow angle with shoot.*

Fine, rounded, almost crenate leaf margins **MM.113**
Almost circular leaves, often faintly lobed .. .. **M.VII**
Very straight shoots with bright red buds and petioles and long tapering leaves **M.VIII**

b. *Petioles outturned forming wide angle with shoot.*

Leaves fairly flat with finely serrate margins **MM.103**
Petioles distinctly kinked near base **MM.114**
Leaves rather crinkled with coarsely serrate, ragged margins **MM.115**

Fig. 1.

Malling-Merton 101. Stout, stiff, erect, somewhat zigzagged shoots with brownish orange raised lenticels ; somewhat upturned leaves with large serrate stipules.

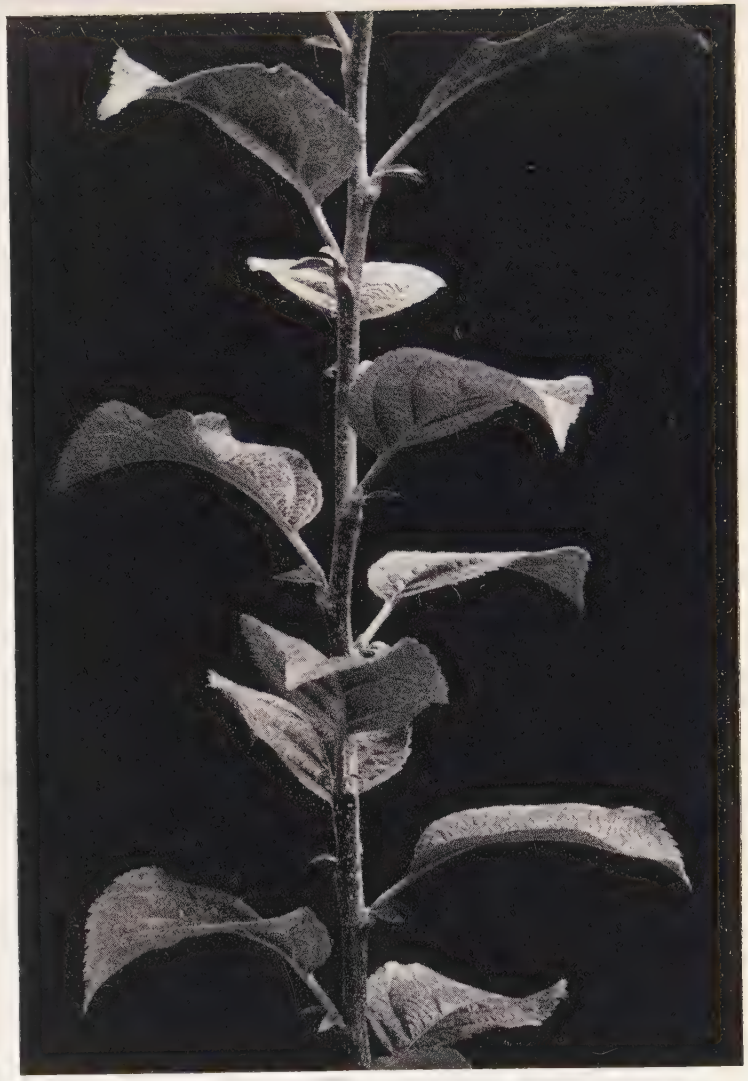


Fig. 2.

Malling-Merton 102. Rather zigzagged shoots with sharp bud bases and slightly ragged buds ; leaves with down-turned and twisted tips, serrations downturned and often tipped with reddish brown.

[face p. 60

FIG. 3.

Malling-Merton 103. Flexible, slender shoots with long ridges and ashen grey buds ; flat or slightly convex leaves with out-turned leaf stalks.

FIG. 4.

Malling-Merton 104. Shoots with numerous, conspicuous lenticels and bright red buds ; upfolded concave leaves with upturned margins and brilliant wine red, much out-turned leaf stalks.

FIG. 5.

Malling-Merton 105. Shoots with a metallic lustre, slightly raised lenticels and red buds; rather flat leaves with much drawn-out, acute tips and wedge shaped, often unequal bases.

FIG. 6.

Malling-Merton 106. Pubescent shoots, somewhat swollen at the node, with indistinct lenticels and ashen grey buds; flattish, horizontal, rather glossy leaves with long, much out-turned stalks.

FIG. 7.

Malling-Merton 107. Stout, flexible, pubescent shoots ; deep green, very glossy leaves, rather flat and horizontal with downturned and twisted tips, short, upturned stalks and large, spreading stipules.

FIG. 8.

Malling-Merton 108. Stocky, straight shoots with a slight metallic lustre, somewhat striated, with short internodes and few, large lenticels ; broad, upfolded leaves, short upturned stalks and smallish stipules.

FIG. 9.

Malling-Merton 109. Shoots with fairly numerous, slightly raised lenticels and reddish buds ; upturned and upcupped leaves with acutely serrate margins, raised and frilled in short waves, long upturned stalks, and small stipules.

FIG. 10.

Malling-Merton 110. Stout, stiff, spreading, ridged shoots with fairly long internodes ; very numerous, slightly raised lenticels ; flat or slightly convex leaves with downturned margins ; large, serrate, spreading stipules.

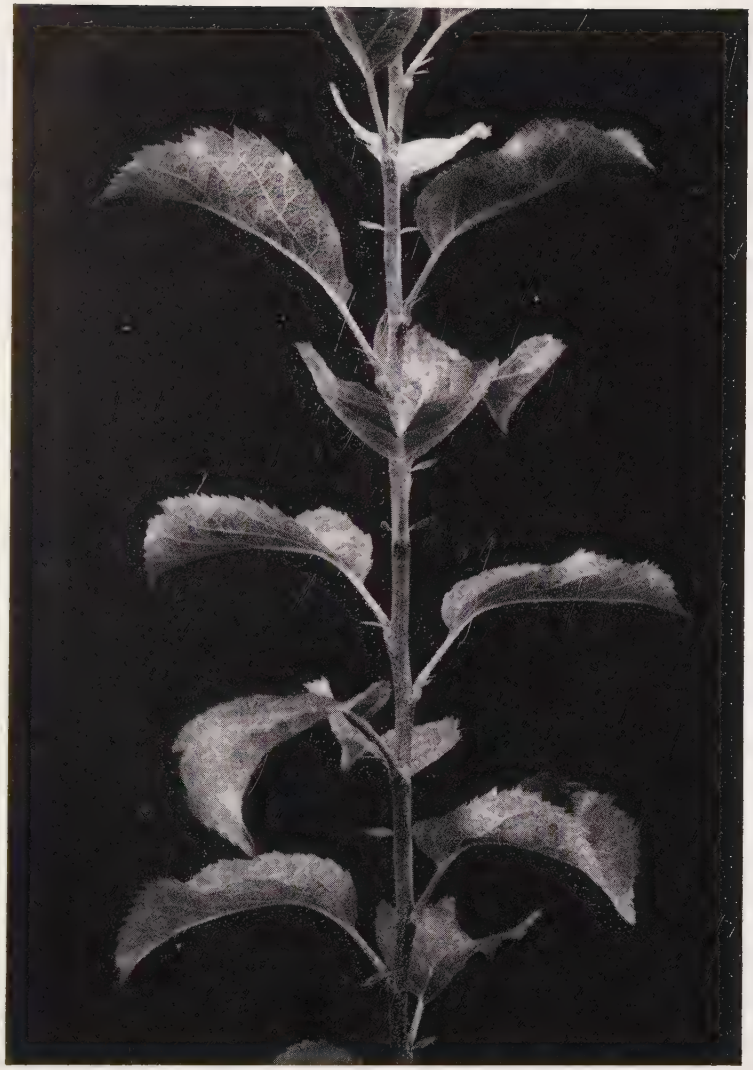


FIG. 11.

Malling-Merton 111. Stout, stiff, erect shoots, considerably swollen at the nodes with rather ragged, ashen grey buds ; upcupped leaves with raised, wavy margins, coarse serrations often tipped with red, and stalks often lumpy at the base.

FIG. 12.

Malling-Merton 112. Flexible, somewhat zigzagged shoots with some pubescence ; flattish, slightly convex, crinkled leaves with downturned and twisted tips, short out-turned stalks and large serrate stipules.

FIG. 13.

Malling-Merton 113. Slender, spreading, flexible shoots, somewhat swollen at the nodes, with deep brownish orange lenticels ; large, upcupped leaves with fine rounded, almost crenate edges, and short upturned stalks.

FIG. 14.

Malling-Merton 114. Stoutish, erect, flexible, distinctly ridged shoots with shortish internodes ; shallowly upfolded leaves much downturned and curved-over ; out-turned leaf-stalks distinctly kinked at the base.

FIG. 15.

Malling-Merton 115. Stoutish, spreading, flexible shoots with longish internodes, much swollen at the nodes, with ragged ashen grey buds much extended below · large, rather oblong leaves with downturned tips and upturned, rather ragged, waved margins.

FIG. 16.

Malling XXV. Erect, stocky, stiff shoots with short internodes and plump, reddish buds ; smallish, flat or convex, much crinkled leaves often slightly downturned ; sea-green.

Malling-Merton 101.

Malling-Merton 102.

Malling-Merton 103.

Malling-Merton 104.

FIG. 17.

Leaves of Malling-Merton apple rootstocks.

Malling-Merton 105.

Malling-Merton 106.

Malling-Merton 107.

Malling-Merton 108.

FIG. 18.

Leaves of Malling-Merton apple rootstocks.

Malling-Merton 109.

Malling-Merton 110.

Malling-Merton 111.

Malling-Merton 112.

FIG. 19.

Leaves of Malling-Merton apple rootstocks.

Malling-Merton 113.

Malling-Merton 114.

Malling-Merton 115.

Malling XXV.

FIG. 20.

Leaves of Malling-Merton and Malling XXV apple rootstocks.

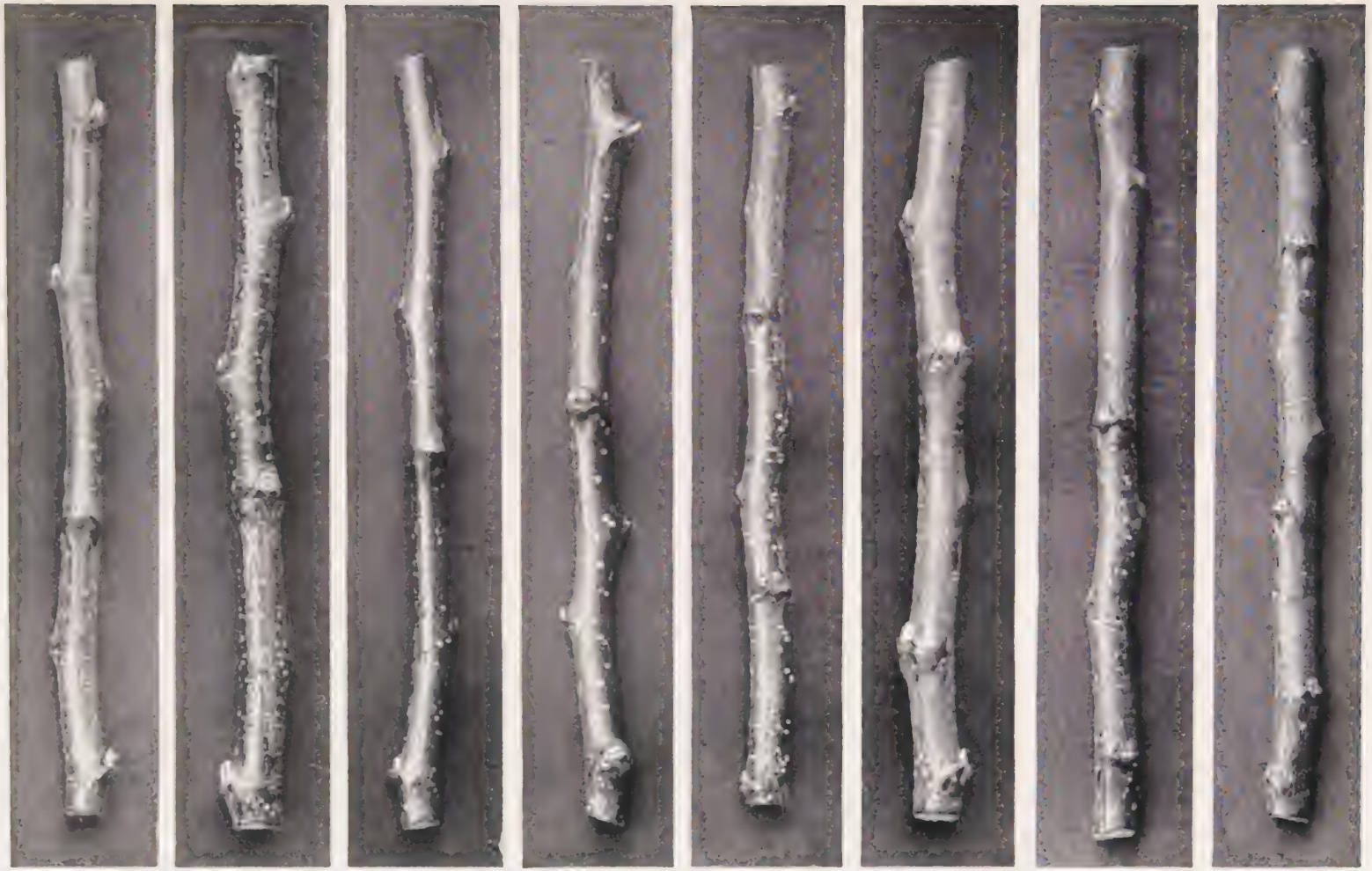


FIG. 21

Dormant shoots of Malling-Merton apple rootstocks.

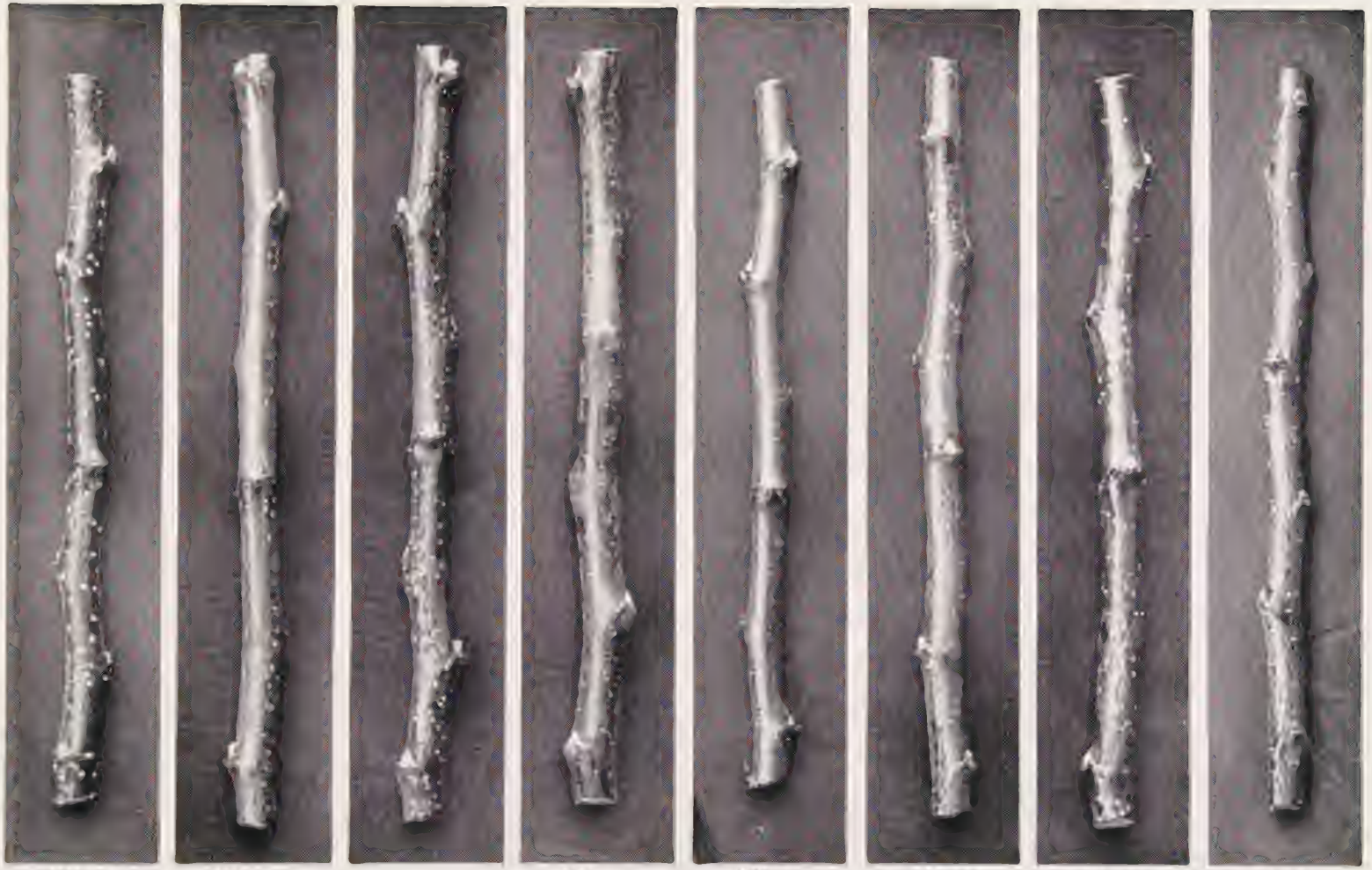
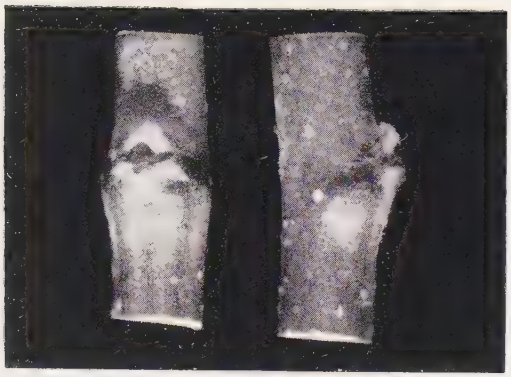
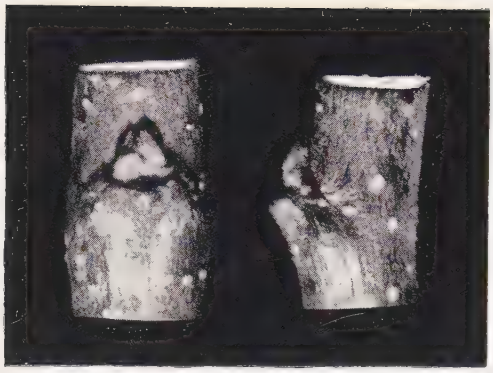


FIG. 22.

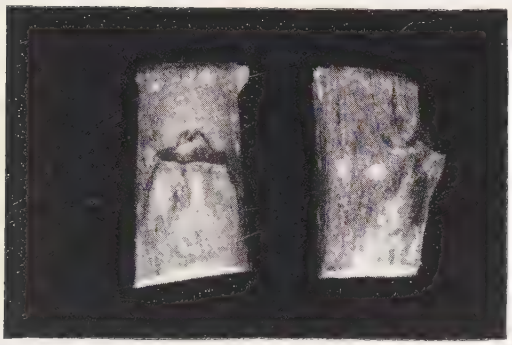
Dormant shoots of Malling-Merton and Malling XXV apple rootstocks.



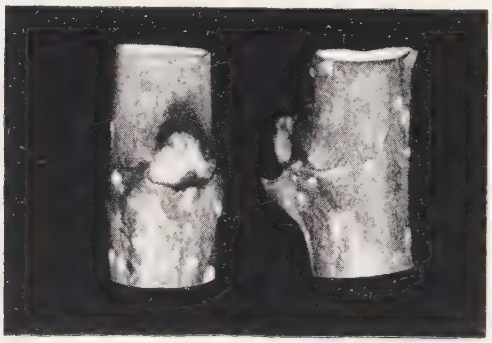
MM.101



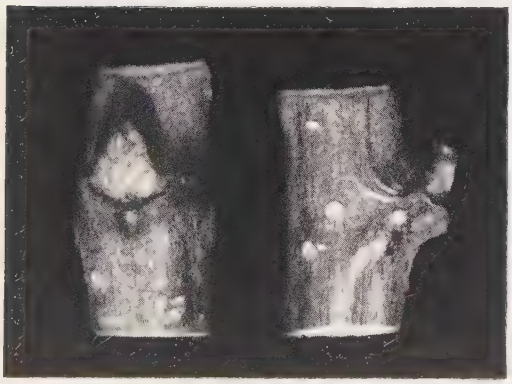
MM.102.



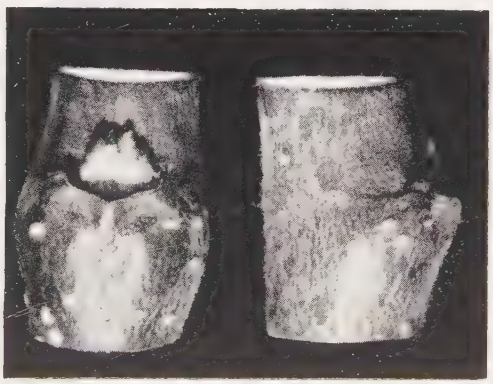
MM.103.



MM.104.



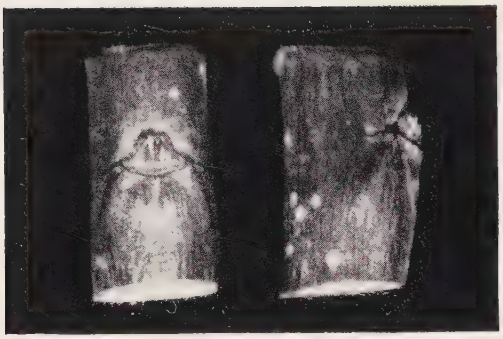
MM.105.



MM.106.

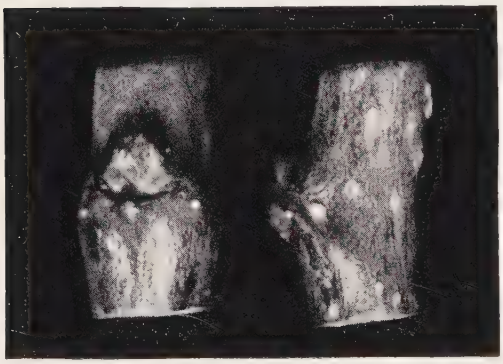
FIG. 23.

Nodes and buds (enlarged) of Malling-Merton apple rootstocks in winter.

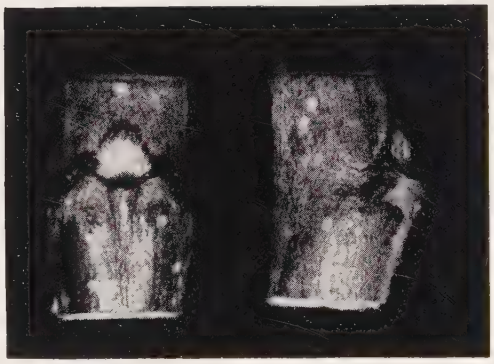


MM.107.

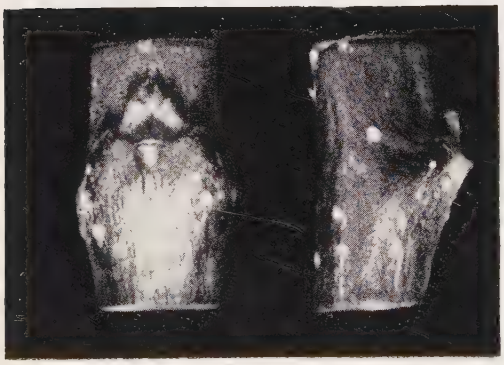
MM.108.



MM.109.



MM.110.

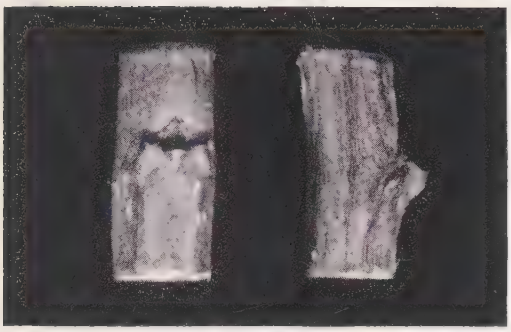


MM.111.

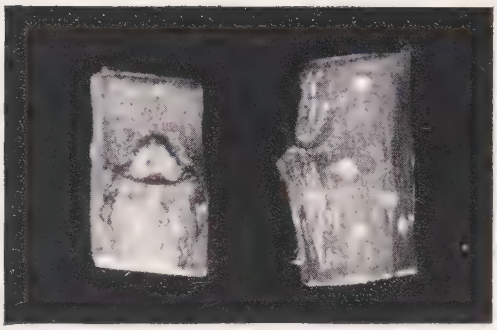
MM.112.

FIG. 24.

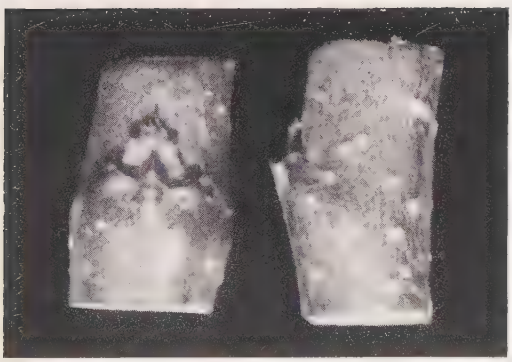
Nodes and buds (enlarged) of Malling-Merton apple rootstocks in winter.



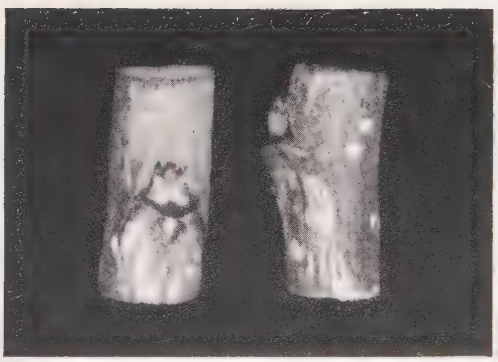
MM.113.



MM.114.



MM.115.



M.XXV.

FIG. 25.

Nodes and buds (enlarged) of Malling-Merton and Malling XXV apple rootstocks in winter.

B. Lenticels few or very few.

1. Stipules large, more than half as long as petioles.

a. *Petioles very erect forming narrow angle with shoot.*

Zigzagged shoots, short internodes and flattish, rounded leaves .. .. **M.XV**

2. Stipules small, linear-lanceolate or crescent-shaped.

a. *Petioles very erect forming narrow angle with shoot.*

Very acutely, coarsely serrate leaves .. .. **M.III**
Heart shaped leaves, often with notched bases .. .. **M.IV**
Very straight shoots with yellow brown wood and distinct metallic sheen .. **M.IX**
Leaves much curved over with downturned tips .. .. **M.XIV**

b. *Petioles outturned forming wide angle with shoot.*

Very drawn-out, acuminate leaf tips with red buds .. .. **M.V**

FROM WINTER CHARACTERS

I. SHOOTS STIFF TO VERY STIFF WITH NUMEROUS OR FAIRLY NUMEROUS LENTICELS.

A. Bases of buds much extended and/or shoots much swollen at the node.

1. Internodes not noticeably short, often long or fairly long.

a. *Buds relatively large, usually more than half as broad as shoot.*

Reddish brown shoots with sharp bud bases and very numerous conspicuous lenticels **MM.102**
Purple brown, rough shoots with conspicuous, raised lenticels, and deep red rather pointed buds **MM.109**

b. *Buds rather small, usually less than half as broad as shoot.*

Purple brown, pubescent shoots, brownish, raised lenticels, and rather blunt buds **MM.101**
Reddish brown shoots, slightly raised lenticels and small grey buds with much clawed bases .. .. **Northern Spy**
Stout, purple brown, pubescent shoots with greyish buds .. .. **Ivory's Double Vigour**

2. Internodes decidedly short.

a. *Buds relatively large, usually more than half as broad as shoot.*

Reddish brown shoots with many lenticels and deep red rather rounded buds **MM.104**
Purple brown, smooth shoots, buds often rather ragged **MM.111**
Reddish or greenish brown shoots, indistinct lenticels, and ashen grey buds **M.VI**

b. *Buds rather small, usually less than half as broad as shoot.*

Chocolate brown, pubescent shoots with indistinct lenticels and ashen grey buds **MM.106**

B. Bases of buds not much extended, shoots fairly even at the node.

1. Internodes not noticeably short, often long or fairly long.

a. *Buds relatively large, usually more than half as broad as shoot.*

Deep chocolate brown, shiny shoots, flattened below the buds ; deep orange brown lenticels ; rounded, reddish buds .. .. **M.XII**

b. *Buds rather small, usually less than half as broad as shoot.*

Chocolate brown, ridged shoots with green patches ; large, slightly raised lenticels **MM.110**

2. Internodes decidedly short.

a. *Buds relatively large, usually more than half as broad as shoot.*

Smooth, reddish brown shoots with metallic sheen ; large, slightly raised lenticels and reddish buds **MM.105**
Dark purple brown shoots, large, conspicuous lenticels, and reddish buds .. **M.II**

b. *Buds rather small, usually less than half as broad as shoot.*

Blackish brown, smooth, shiny shoots, conspicuous lenticels, and sooty red buds .. .. **M.X**
Chocolate brown, striated shoots with plump, greyish red buds .. .. **M.XXV**

II. SHOOTS FAIRLY FLEXIBLE WITH NUMEROUS OR FAIRLY NUMEROUS LENTICELS.

A. Bases of buds much extended and/or shoots much swollen at the node.

1. Internodes not noticeably short, often long or fairly long.

b. *Buds rather small, usually less than half as broad as shoot.*

Deep reddish brown, grained shoots with long ridges and pale ashen grey buds — **MM.103**
Greyish brown, much ridged shoots with brownish orange lenticels — **MM.113**
Purple brown, ridged shoots with green patches, conspicuous lenticels, and slightly ragged buds — **MM.115**
Chocolate brown, grained and ridged shoots with much pubescence, deep orange lenticels, and blackish red buds — **Crab C**

B. Bases of buds not much extended, shoots fairly even at the node.

1. Internodes not noticeably short, often long or fairly long.

a. *Buds relatively large, usually more than half as broad as shoot.*

Purple brown, zigzagged, ridged shoots with light grey buds. — **M.I**
Purplish brown, smooth shoots ; plump, greyish red, slightly outturned buds — **M.VIII**

b. *Buds rather small, usually less than half as broad as shoot.*

Dark reddish brown ridged shoots with little pubescence — **MM.112**
Bright purplish brown, smooth shoots with crescent-shaped buds — **M.VII**

2. Internodes decidedly short.

a. *Buds relatively large, usually more than half as broad as shoot.*

Reddish brown, ridged shoots ; conspicuous lenticels ; reddish brown, pointed buds — **M.XI**

b. *Buds rather small, usually less than half as broad as shoot.*

Pale purple brown, much ridged shoots, small lenticels and sooty red buds — **MM.107**
Reddish brown, striated shoots with brownish yellow, almost orange lenticels — **MM.114**
Deep reddish brown shoots with conspicuous, whitish lenticels — **M.XIII**

III. SHOOTS STIFF TO VERY STIFF WITH FEW OR VERY FEW LENTICELS.

B. Bases of buds not much extended, shoots fairly even at the node.

1. Internodes not noticeably short, often long or fairly long.

a. *Buds relatively large, usually more than half as broad as shoot.*

Purplish brown shoots, rather flat, ragged, dark red buds — **M.XVI**

2. Internodes decidedly short.

b. *Buds rather small, usually less than half as broad as shoot.*

Pale greyish brown, shiny shoots with large lenticels — **MM.108**

IV. SHOOTS FAIRLY FLEXIBLE WITH FEW OR VERY FEW LENTICELS.

B. Bases of buds not much extended, shoots fairly even at the node.

1. Internodes not noticeably short, often long or fairly long.

a. *Buds relatively large, usually more than half as broad as shoot.*

Dark purple brown shoots, long, pointed greyish buds with ragged tips — **M.III**

b. *Buds rather small, usually less than half as broad as shoot.*

Light reddish brown, shiny, straight shoots with light greyish, rather ragged, slightly outturned buds — **M.IX**
Purple brown, grained shoots, ridged below the buds with small, greyish red buds — **M.XIV**

2. Internodes decidedly short.

b. *Buds rather small, usually less than half as broad as shoot.*

Light brown, grained shoots with small, dark red buds — **M.IV**
Reddish brown, straight shoots, dark red, slightly outturned buds, few, large lenticels — **M.V**
Dark purple brown shoots with reddish, ragged buds — **M.XV**

NOTE.—**MM.**=Malling-Merton. **M.**=Malling.

Acknowledgement.

The photographs were taken by Mr. E. Yoxall Jones to whom the writer makes grateful acknowledgement.

Summary.

Descriptions and illustrations are given of the fifteen Malling-Merton apple rootstocks and of Malling XXV. These rootstocks were bred at Merton and East Malling and are now being distributed for trial.

Keys are provided for their identification in summer and winter, and for their separation from their parents and from other apple rootstocks of the older Malling series.

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THE NURSERY BEHAVIOUR OF THE MALLING-MERTON AND MALLING XXV APPLE ROOTSTOCKS

By R. J. GARNER

The origin and botanical characters of these rootstocks have been described (Tydeman, 1953) and the behaviour in the plantation of trees worked upon them has been summarized (Preston, 1953a, 1953b). Following preliminary observation of propagation qualities, the eight hundred clones originally under test were, in 1940-1, classified into vigour groups by anatomical characters (Beakbane, Thompson, and Tydeman, 1941), and fifty-five clones were selected for further propagation. In 1944-5 stoolbeds of twenty of these, four from each of five groups covering the vigour range, were extended to provide a thousand rootstocks of each clone. Detailed observations of propagation qualities were made throughout the period of selection and re-selection and in 1948-9 a number of clones were set out to form stoolbeds capable of an annual production of ten thousand rootstocks each. At the same time, other clones were maintained in smaller units awaiting the results of plantation trials. Information gained from the plantation trials and accumulated observations of nursery behaviour, together with a thorough retest for resistance to the Woolly Aphid, led to the formation of the Malling-Merton series of rootstocks numbered from MM.101 to MM.115 inclusive to distinguish them from the Malling series. At the same time one vigorous yet precocious clone, not highly resistant, was added to the Malling series as M.XXV.

Behaviour in the stoolbed.

The nursery performance of any one rootstock depends upon a number of differing factors such as soil variation from field to field, climate from year to year and, above all, seasonal management. Hence, when judging a rootstock, it is necessary to consider many factors, and their interaction, and something is always left to judgement. Reference to notes made over a period of ten years reveals changes here and there in the comparative performance of the series, but even so the rootstocks, with few exceptions, have tended to behave similarly from year to year. The principal features which combine to decide the practicability of stoolbed propagation are set out in Table I. Stoolbed yield is

TABLE I.

BEHAVIOUR IN THE STOOLBED OF THE MALLING-MERTON AND M.XXV ROOTSTOCKS RELATIVE TO MEMBERS OF THE MALLING SERIES.

Rootstock.	Shoot production.	Side-shoots and spines.*	Rooting.	Season of leaf fall.
MM.101	Very high	Slightly spiny	Good	Mid
MM.102	Medium	Nearly clean	Good	Mid
MM.103	High	Many laterals	Poor	Late
MM.104	Very high	Spiny	Good	Mid
MM.105	Very high	Slightly spiny	Good	Early
MM.106	Medium	Slightly spiny	Medium +	Late
MM.107	Low	Slightly spiny	Medium +	Late
MM.108	Low	A few spines	Good	Late
MM.109	Very high	Clean	Good	Early
MM.110	Very high	Some laterals	Medium	Mid
MM.111	High	Clean	Good	Mid
MM.112	Very high	A few spines	Medium +	Late
MM.113	High	Spiny	Poor	Very late
MM.114	High	Very spiny	Poor	Late
MM.115	High	Slightly spiny	Medium	Late
M.XXV	High	Spiny	Medium +	Mid
M.II	Very high	Very spiny	Poor to Medium	Early
M.VII	Medium	Clean	Good	Mid
M.IX	Very low	Slightly spiny	Medium	Mid
M.XVI	High	Slightly spiny	Medium +	Very late
Malling Crab C	High	Slightly spiny	Poor	Late

* See text under ' Behaviour in the stoolbed '.

decided by a combination of shoot production with rooting and thus high shoot production can, to a limited extent, offset poor rooting and good rooting offset low shoot production. Nevertheless, the combination of high shoot production with good rooting is obviously of great value, as in MM.101, 104, 105, and 109.

Shoot laterals and spines impede harvesting, grading, and bundling and, whilst they are less prevalent in mature stoolbeds, they tend to persist where stools grow vigorously, as have those on which the observations recorded in Table I were made. Under similar conditions the rootstocks II and VII of the Malling series would be classified as ' very spiny ' and ' clean ' respectively.

Stoolbed shoots are normally harvested in the autumn, and rootstocks which hold their leaves very late must either be defoliated artificially or harvested in mid-winter. There is evidence that the weather of the previous months has some effect on time of leaf fall as has soil condition. In the Malling series both XIII and XVI are very slow to defoliate.

Behaviour when lined-out.

In general, the rootstocks under review have given evidence of good transplanting quality. Though this quality is largely determined by the amount of root present at planting, it is also partly due to the power to form new roots readily from the stem. On one occasion MM.107, 110, 112, 114, and 115 gave somewhat uneven stands, as M.II will do at times, and this may indicate that one should avoid planting poorly rooted specimens of these.

None of the Malling-Merton series nor M.XXV has shown any signs of incompatibility when budded with a range of varieties including Cox's Orange Pippin, Ellison's Orange, Lane's Prince Albert, and Jonathan. Following reports from North America that certain rootstocks of Northern Spy parentage had proved incompatible in the nursery with scions of McIntosh Red, a range of clones, from which nine of the Malling-Merton series were later selected, was worked with that variety and Cox's Orange Pippin. The buds took well and the trees remained in the nursery for four years without showing signs of stock/scion incompatibility.

In 1944 an outbreak of Apple Mildew in a nursery of bedded rootstocks provided an opportunity of observing the incidence of this disease amongst the Malling-Merton series. A further outbreak in 1951 showed, with few exceptions, similar incidence. The MM.108, 113, and 114 have, like M.II and M.XVI, shown rather less Mildew than the average, whilst 106 and 109, in two seasons, behaved similarly to M.IX, which is somewhat susceptible.

Classification by propagation quality.

Having in mind that the ease of multiplication of a rootstock is judged only after amalgamating numerous observations of various characteristics, an attempt has been made to form four groups each approximating to rootstocks with which nurserymen are familiar.

Group A.—Excellent : MM.101, 104, and 105 (corresponding to M.V, XI, or XIII).

These rootstocks are very readily propagated ; an acre of established stools should yield annually forty thousand rootstocks fit to line out for working and some twenty to thirty thousand for bedding.

Group B.—Good : MM.102, 106, 107, 108, 109, 110, 111, 112, and 115 (corresponding to M.I, II, IV, VII, or XVI).

This group contains those rootstocks which are sufficiently productive to become readily available to the industry as required. Yields of thirty thousand for working and a similar quantity for bedding should be readily obtainable.

Group C.—Fair : MM.103 and M.XXV (corresponding to M.VIII or XII).

Rootstocks in this group, whilst not so readily multiplied as those in the preceding groups, are capable of being produced in quantity if desired. Recent experience with M.XXV indicates that this rootstock may be as readily propagated as M.XVI, which it resembles in plantation performance, and, if so, it would come in Group B.

Group D.—Poor : MM.113 and 114 (corresponding to Malling Crab C, Northern Spy, and Ivory's Double Vigour).

In this group come those stocks which root very poorly under the stoolbed system, except in extremely favourable circumstances. These rootstocks may respond better to other methods of propagation such as layering, involving etiolation, or root-cuttings, although such methods are considerably more troublesome than stooling.

Large-scale production.

In 1952 four of the Malling-Merton rootstocks, MM.104, 106, 109, and 111, and M.XXV, together with M.II, VII, and XVI, were harvested from a considerable area of stoolbeds which were then three years old.

Full use had been made of commercial methods of production and no special treatment was used. Production figures are set out in Table II. It will be noted that the production of M.II is very low, as is common with this rootstock until the stools are really well established, some five years or so from planting, when production normally exceeds thirty thousand fit to line out for working ; a satisfactory stoolbed crop for any apple rootstock.

TABLE II.

PRODUCTION PER ACRE OF STOOLBEDS IN THEIR THIRD YEAR, IN THOUSANDS.

Rootstock.	Fit to bud.	For bedding.	Total.
MM.104	43	33	76
MM.106	42	12	54
MM.109	39	41	80
MM.111	37	28	65
M.XXV	35	13	48
M.II	10*	35	45
M.VII	36	35	71
M.XVI	33	24	57

* See text under ' Large-scale production '.

In conclusion.

The nursery behaviour of the Malling-Merton and Malling XXV rootstocks is comparable with that of the rootstocks already in commerce. A number of the Malling-Merton clones are considerably easier to propagate than the majority of rootstocks, whilst the remainder are equal to their counterparts of similar vigour in the older series.

The four Malling-Merton rootstocks, MM.104, 106, 109, 111, and Malling XXV, have been distributed to rootstock raisers for further multiplication ; the other eleven Malling-Merton rootstocks are not at present being released for general use, but will continue under test in nursery and orchard.

Summary.

The behaviour of the Malling-Merton and Malling XXV apple rootstocks in the nursery is described and compared with older members of the Malling series. Large-scale production figures are given for the four Malling-Merton and Malling XXV rootstocks now available to propagators.

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PRELIMINARY STUDIES OF SPRING FROST RESISTANCE OF BLACK CURRANT VARIETIES

By IRENA MODLIBOWSKA and J. P. RUXTON

The available records of the relative susceptibility of black currants to spring frost damage are based mainly upon subjective estimates of damage made in the field following a frost, and on the differences observed in the cropping of varieties in frost and non-frost years, from which no very clear picture results.

Experience at East Malling (Painter and Wates, 1936 ; Hatton and Amos, 1936 ; and Hatton *et al.*, 1942) suggests that of the varieties Baldwin, Boskoop Giant, Seabrook's Black, Goliath, and Wellington XXX, Baldwin has a tendency to be the least damaged by frost. On one occasion, however (Amos, 1939), the later flowering Goliath was much less damaged than the other, earlier flowering varieties. Amos *et al.* (1942) drew attention to the fact that frost just before blossoming in 1936 did more damage to black currants than did the more generally damaging frost in 1935, which occurred after they had completed their blossom season.

At Long Ashton, Spinks and Swarbrick (1936) reported that in 1935, when frost occurred after the majority of the blossom had set, Boskoop was more damaged than Seabrook's. On Baldwin, although late blossoms were killed, fruits which had set were not affected. Westwick Choice was another variety which suffered little. Spinks and Clothier (1939) reported that damage in 1938 varied little from one variety to another, Seabrook's and Boskoop possibly suffering less injury than Baldwin.

Bush (1945) records that over a period of years his best performer was the Hilltop strain of Baldwin, followed by Boskoop and Davison's Eight, with Seabrook's, usually regarded as a frost resistant variety, the worst performer of the four. Wakil (1952) reported that the varieties Wellington XXX and Baldwin, flowering earlier than Boskoop, were more heavily damaged than was the latter. He showed that damage to each of the varieties was greater near the ground than it was higher up the bush.

Spring frost damage to black currants should not be confused with the familiar phenomenon of ' running off '. Both Hatton (1921) and Ledeboer and Rietsema (1937) have stressed this. The flowers drop off shortly after the incidence of frost damage. ' Running off ', on the other hand, affects the young fruitlets from towards the end of May to early June, and is primarily due to incomplete pollination.

The present study deals with seven laboratory experiments and one set of field observations at East Malling.

Laboratory experiments.

Materials and methods.

Two types of material were used—racemes cut from bushes, usually growing in the field, and bushes grown in pots specially for the purpose.

Cut racemes.—A random sample of ten racemes was cut from five bushes of each variety to be tested, each raceme bearing both open flowers and buds. Each raceme, as soon as it was cut, was placed with its severed end in water.

The racemes were transferred to the cold chamber where each had its cut end wrapped in a piece of wet cotton wool and was mounted on a horizontally rotating wheel. The varieties were randomly distributed. Fine wire, 40 s.w.g. copper-constantan, thermocouples (Slater, 1953) were inserted in buds or flowers mounted on a rack. The thermocouples were connected either to a manual potentiometer or to a Foster 6-point recording galvanometer. An air thermocouple was attached to the centre of the rack and another was suspended over the centre of the wheel. The racemes were lightly sprinkled with water to simulate dew formation and two fans in opposite corners of the room and facing vertically upwards were switched on.

The temperature of the room was lowered steadily to the desired minimum at a rate of 1·2° C. (2·2° F.) per hour, where it was maintained for a given period of time. Two electric heaters were then switched on, warming the room at a rate comparable to the rate of rise in temperature experienced after frost under natural conditions.

The thawed racemes were placed with their cut ends in water and kept overnight at a temperature of 20° C. (68° F.) ; on the following day records of damage were taken.

Plants in pots.—Plants grown in pots under outdoor conditions were taken into a room, maintained at 10° C. (50° F.) during the day preceding the experiment, watered so that the soil in the pots was saturated, and left overnight. Usually four plants of each variety were taken, two for freezing and two for controls.

The following morning thermocouples were inserted in blossoms at the appropriate stage of development and at a standard height. After being transferred to the cold chamber the pots were covered with cardboard discs, fitting round the stems of the plants, and were also surrounded with a cylinder of corrugated cardboard to reduce heat losses.

The plants were sprinkled with water and freezing was carried out in the same manner as described for cut racemes.

Results.

Experiments 1 and 2.—These were carried out in 1950, when two varieties, Westwick Triumph, claimed to be frost resistant, and Boskoop Giant, as representative of the average susceptible variety, were compared. Both bushes in pots and cut racemes were used.

Two ways of recording damage were compared in these two experiments. One method is based on the discoloration of the styles of both buds and flowers, whilst the other depends upon the fact that frost-damaged buds and flowers shrivel up very soon after freezing. No significant difference was recorded between the results obtained from the two methods and, since the latter is more economical of time and labour, it was used throughout the experiments.

The results (Table I) show that, on the basis of damage to blossom on bushes in pots, Westwick Triumph was less damaged than Boskoop. The damage to blossoms on cut racemes, however, did not show this difference. Damage to cut racemes was much greater than that to bushes in pots, which may be due to the experimental conditions being too severe for this type of material. This difference did not seem to be accounted for on the basis of protection afforded by foliage to blossoms on bushes, there being no relation between the amount of damage and the amount of foliage.

TABLE I.

PERCENTAGE OF FROST DAMAGE TO BOSKOOP GIANT AND WESTWICK TRIUMPH AT DIFFERENT STAGES OF DEVELOPMENT, USING BOTH CUT RACEMES AND BUSHES IN POTS.

Experiment.	Minimum temperature.	Duration of minimum temperature.		Stage of development.	Boskoop Giant.			Westwick Triumph.	
					Bushes in pots.	Racemes cut from :		Bushes in pots.	Racemes cut from bushes in pots.
		hrs.	mins.			Bushes in pots.	Bushes in the field.		
1 2nd May, 1950	−4·2° C. (24·5° F.)	2	05	Buds	91·8	100	100	73·2	100
				Flowers	79·5	94·8	87·2	60·1	100
				Mean	84·2	97·0	92·9	63·7	100
2 5th May, 1950	−4·0° C. (24·8° F.)	1	45	Buds	94·9	97·3	90·0	74·2	96·1
				Flowers	84·5	92·2	90·3	69·1	94·5
				Fruitlets	58·9	—	—	84·0	—
				Mean	81·2	94·4	90·3	74·6	95·2

Generally, damage was greater at the bud stage than at the open flower stage, an important point, since the more common experience with other fruit blossom is that buds are less damaged than are open flowers.

The crop records (Table II) show that exposing the bushes to low temperature caused a decrease in the crop as compared with the bushes not so exposed. The crop of the more heavily damaged variety Boskoop was somewhat lower than that of Westwick Triumph, both actually and proportionately.

Experiments 3, 4 and 5.—The first two were carried out in 1950 and the third in 1951, using cut racemes of the varieties Baldwin, Boskoop Giant, Cotswold Cross, Goliath, Mendip Cross, Seabrook's Black, Wellington XXX, and Westwick Choice.

Table II.

Cropping of Boskoop Giant and Westwick Triumph grown in pots in relation to frost damage.

Experiment.	Treatment.	Boskoop Giant (Hgm.)	Westwick Triumph (Hgm.)
1 2nd May, 1950	Bushes subjected to frost .. .. .. Controls	3 24	7 27
2 5th May, 1950	Bushes subjected to frost .. .. .. Controls	6·5 25	7 15

The results (Table III) show the varieties arranged in order of the stage of development of the blossom, Baldwin being most and Goliath least advanced. Baldwin, Boskoop, Wellington XXX, and Westwick Choice formed a group which was earlier flowering than the other varieties.

Table III.

Percentage of frost damage to eight black currant varieties, using cut racemes.

Experiment.	Minimum temperature.	Duration of minimum temperature. hrs.	mins.	Stage of development.	Baldwin.	Boskoop Giant.	Wellington XXX.	Westwick Choice.	Mendip Cross.	Cotswold Cross.	Seabrook's Black.	Goliath.
3 2nd May, 1950	−4·2° C. (24·5° F.)	2	05	Buds	100	100	96·1	100	100	91·4	97·2	100
				Flowers	100	87·2	78·4	90·6	98·1	74·2	58·9	100
				Mean	100	92·9	85·2	93·8	98·9	82·9	77·9	100
4 5th May, 1950	−4·0° C. (24·8° F.)	1	45	Buds	88·9	90·0	100	87·5	87·5	81·5	96·0	94·5
				Flowers	88·9	90·3	88·1	78·8	91·3	80·9	69·2	89·1
				Mean	88·9	90·3	91·6	81·7	89·9	81·1	79·8	91·8
5 15th May, 1951	−3·0° C. (26·6° F.)	2	00	Buds	42·9	75·0	47·4	66·7	61·1	58·3	64·3	55·6
				Flowers	25·4	22·1	33·9	32·1	54·1	33·8	30·5	52·1
				Mean	26·0	28·6	36·0	37·1	55·1	37·0	37·6	52·7

From the results it is clear that buds were usually more susceptible to damage than the open flowers. Seabrook's Black and Cotswold Cross tended to be the least damaged whilst Mendip Cross and Goliath were the most damaged. The results are, however, variable.

Experiments 6 and 7.—These were carried out in 1951 and 1952 respectively, using bushes in pots of the five varieties Amos Black, Baldwin, Boskoop Giant, Seabrook's Black, and Wellington XXX. A small amount of damage was caused in 1951 by a natural frost on the night of 21st-22nd April. This is applied as a correction to the damage which occurred in experiment 6 (Table IV).

In experiment 6 the temperature of the room was lowered to −3·0° C. (26·6° F.) and maintained at this level for 1 hour 50 minutes. Records of damage were taken on the following day, when all flowers and buds were examined.

The results (Table IV) show that, except for Wellington XXX, buds were again more heavily damaged than open flowers. The varieties are arranged in order of the stage of development of the blossoms. Seabrook's Black and Amos Black were clearly the least damaged and Wellington XXX the most damaged. The results suggest that the smaller amount of damage to Seabrook's may be associated more with the open flower stage than with the bud stage.

In experiment 7 the temperature of the room was lowered to −3·5° C. (25·8° F.) where it was maintained for about 30 minutes. When records of damage were taken, on the day following freezing, alternate racemes were removed from the bushes, and the buds and blossoms cut to examine for damage. From these records the stage of development, given as the percentage of open flowers, was calculated. Crop records were taken, the mean fruit set per bush, expressed as a percentage of the buds and flowers left on, and the mean weight per fruit were calculated.

TABLE IV.

PERCENTAGE FROST DAMAGE TO FIVE BLACK CURRANT VARIETIES IN POTS. EXPERIMENT 6, 8TH MAY, 1951.

		Baldwin.	Wellington XXX.	Seabrook's Black.	Boskoop Giant.	Amos Black.
Frost damage (corrected from controls)	Buds	36·4	41·9	25·0	50·0	18·9
	Flowers	31·6	48·5	7·6	37·9	11·9
	Mean	31·9	47·1	8·7	39·3	13·4

The results (Table V) show that Baldwin was the earliest flowering and Amos Black the latest. Seabrook's and Amos Black were again the least damaged and Boskoop, changing places with Wellington XXX, the most damaged. There was no consistent correlation between the relative susceptibility and the stage of development of varieties. Damage was greater to buds than it was to open flowers.

TABLE V.

FROST DAMAGE AND CROP RECORDS OF FIVE VARIETIES OF BLACK CURRANT, GROWN IN POTS. EXPERIMENT 7, 18TH APRIL, 1952.

		Baldwin.	Wellington XXX.	Seabrook's Black.	Boskoop Giant.	Amos Black.
Percentage of open flowers		67·8	45·8	41·9	33·2	25·7
Frost damage (per cent)	Buds	42·1	42·1	5·1	45·5	6·5
	Flowers	8·4	14·1	2·2	16·4	3·1
	Mean	19·3	29·5	3·9	35·9	5·3
Fruit set (per cent)	Frozen	67·8	59·8	77·9	51·1	78·9
	Controls	87·9	88·8	90·0	69·2	87·0
Mean crop per bush (Hgm.)*	Frozen	1·8	2·1	1·8	1·3	1·7
	Controls	2·7	4·3	1·5	1·9	1·8
Mean weight per fruit (g.)	Frozen	0·43	0·63	0·47	0·56	0·61
	Controls	0·39	0·51	0·44	0·55	0·63

* Crop from half the original blossoms.

In all varieties the percentage of fruit set on the bushes subjected to frost conditions was less than on the controls. Freezing also reduced the yield per bush, except for Seabrook's Black. The mean weight per fruit was very little different on the frozen bushes from that on the controls, except in the case of Wellington XXX where it was much greater ; this variety, though it had the heaviest crop, suffered the greatest reduction in yield.

Field observations in 1951.

Following the occurrence of a natural frost on the night of 21st-22nd April, 1951, when the grass minimum was 25° F. and the screen minimum 32° F., a record of damage was taken four and five days later, on ten bushes of each of a number of varieties growing in the field, and upon two bushes of each of five varieties growing in pots near the glasshouses.

The results (Table VI) show that the least damaged varieties in the field were Goliath, Seabrook's Black, and Boskoop Giant which were also the latest flowering. The most damaged varieties, Westwick Choice and Baldwin, were earlier flowering, whilst Cotswold Cross, the earliest flowering variety, was intermediate in terms of damage suffered. There is considerable agreement between these results and those from the bushes in pots growing on the glasshouse plot. On the latter, however, Amos Black was markedly less damaged than the other varieties.

In this case varieties with open flowers suffered most.

TABLE VI.

PERCENTAGE DAMAGE TO NINE BLACK CURRANT VARIETIES FROM NATURAL FROST ON NIGHT OF 21ST-22ND APRIL, 1951.

Variety.	Stage of development.	Bushes in the field.	Bushes in pots.
Amos Black	Buds	—	10
Goliath	Buds	5	—
Seabrook's Black	Buds	18	53
Boskoop Giant	Buds	42	72
Mendip Cross	25% open flowers	48	—
Westwick Choice	25% open flowers	84	—
Baldwin	<50% open flowers	73	85
Wellington XXX	<50% open flowers	69	92
Cotswold Cross	50% open flowers	52	—

Discussion.

Results show that none of the varieties tested was markedly resistant to frost. Moreover, they suggest that the reaction of a variety to frost depends on several factors, of which basic resistance is only one. The results with cut racemes, which can be expected to show the basic resistance, are not entirely consistent, but on the whole showed a tendency for Seabrook's Black and Cotswold Cross to be less damaged than the other varieties tested, and for Mendip Cross and Goliath to be more damaged, but often the differences were not large.

The results with bushes in pots, where a lesser number of varieties was tested, show larger and more consistent differences, with Seabrook's Black, again, and Amos Black least damaged of the varieties tried, and Wellington XXX and Boskoop Giant the most damaged. Amos Black was not included in the raceme test.

The figures show that the open flowers of Seabrook's Black were more resistant to frost damage than those of the other varieties tested.

The factor of protection of the racemes from radiation by the foliage is probably important in the field. In the laboratory tests, where there is very little cooling by radiation, the incidence could not be studied.

In the laboratory experiments buds were more damaged than open flowers, which indicates that the black currant, as blossom time approaches, increases in frost susceptibility up to the ' grape ' stage and then, as the blossoms open, becomes more resistant. Thus, while in most years the later flowering varieties (of which Amos Black is an outstanding example) may experience less severe frosts at blossom time and so suffer less frost damage than the earlier flowering ones, in certain years frosts may occur at periods when earlier flowering varieties have passed into the more resistant stage, and later flowering ones are more susceptible. This may explain, in fact, the varying observations on varietal susceptibility in the field.

Clearly, more field experience is desirable and to this end a variety trial has been planted on low-lying land at the Research Station. This, it is hoped, will yield information on many aspects of the problem of varietal susceptibility to spring frost damage during the next few years.

The susceptibility of black currants to early frost damage, shown in these experiments, suggests that special care should be exercised in siting black currant plantations.

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Summary.

Preliminary laboratory and field investigations into the relative spring frost resistance of some black currant varieties showed that none of those tested were markedly resistant, but some varieties tended to be less damaged than others. In the laboratory experiments buds were more damaged than open flowers. The flowers of Seabrook's Black suffered less damage than those of other varieties.

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SOME EXPERIMENTS ON 'WASHING OFF' THE HOAR FROST

By IRENA MODLIBOWSKA

' Washing off ' the hoar frost with water in the early morning following a frosty night has been claimed by some market and amateur gardeners as a method of preventing frost damage to plants. This practice should not be confused with frost protection by *continuous* water sprinkling, which is designed to keep up the plant temperature throughout a frosty period by continuous or rapidly repeated sprinkling (Rogers and Modlibowska, 1950 ; Rogers, 1952).

Opinions as to the value of ' washing off ' the frost in the morning vary, and few controlled experiments have been reported.

Day and Peace (1937) and Field (1942) found that spraying plants with water before thawing had no effect. Chandler (1945) states that " spraying trees in blossom on a frosty morning, to retard thawing, has sometimes caused flowers on these trees to be the only ones killed ". He points out that spraying plants with water accelerates thawing rather than slowing it down. In several experiments with different plants Osterwalder (1943 and 1947) showed that a single spraying of frozen plants with water does not protect them and that, besides being ineffective, it might even be harmful. Kessler and Kaempfert (1940) considered that the results of morning spraying of frozen plants might vary from beneficial to harmful according to the conditions prevailing before and after spraying.

To help to elucidate these conflicting reports, experiments were carried out at East Malling on potato, tomato, and strawberry plants under controlled and natural frost conditions, using fine wire thermocouples, placed within the plant tissues, to show the temperature changes.

Laboratory experiments.

In each laboratory experiment eighteen potato plants, grown in pots, were exposed in a cold chamber to temperatures below 0° C. (32° F.). Whilst in the cold chamber the following three treatments were applied at random : treatment A—six plants sprayed with water half an hour before warming up ; treatment B—six plants sprayed with water immediately before warming up ; treatment C—six control plants not sprayed.

Each plant in treatments A and B was sprayed with about 50 ml. of water, the temperature of which was 5·6° C. (42° F.). The temperature of plants in each treatment was measured by means of fine wire copper/constantan thermocouples (40 S.W.G.) inserted in the midrib of the leaves.

At the end of each experiment, when all the plants had thawed, they were taken to a warm room kept at about 15° C. (59° F.), the damage being recorded two or three days later.

Experiment 1.

In this experiment the plants were exposed to an air temperature below freezing point for one and three-quarter hours, the minimum temperature recorded being −2·4° C. (27·7° F.). They started freezing after ten to twenty minutes when the air temperature was about −1·6° C. (29·1° F.).

Treatment A was applied when the air temperature was about −2·0° C. (28·4° F.), i.e. before the minimum was reached (Fig. 1), and when the temperature of the plant was 0·5° C. (0·9° F.) higher than that of the air. The treatment caused the temperature of the sprayed plant to rise immediately by 0·6° C. (1·1° F.). After this it gradually fell, reaching that of the unsprayed control in about twenty minutes. During warming up the temperature of the sprayed plant lagged behind that of the control owing to the thawing of the ice layer. Treatment B was applied immediately before warming up.

When removed from the cold chamber the plants were already showing a difference. The foliage of the plants sprayed half an hour before warming up was drooping and appeared to be the most damaged, whilst the controls showed least damage (Fig. 2). The record of frost damage, taken three days later (Table I), confirmed that the plants sprayed half an hour before warming up were significantly more damaged than the controls or those sprayed immediately before warming up.

Experiment 2.

The air temperature in this experiment was kept below freezing point for two hours, the minimum temperature recorded being −3·2° C. (26·2° F.).

Plants sprayed with water half an hour before warming up (treatment A) showed an immediate rise in temperature from −3·0° C. (26·6° F.) to −0·5° C. (31·1° F.). Twenty-five minutes after spraying the plant temperature had fallen to that of the controls. The temperature of the plants sprayed immediately before warming up (treatment B) did not fall below −1·2° C. (29·8° F.) after spraying.

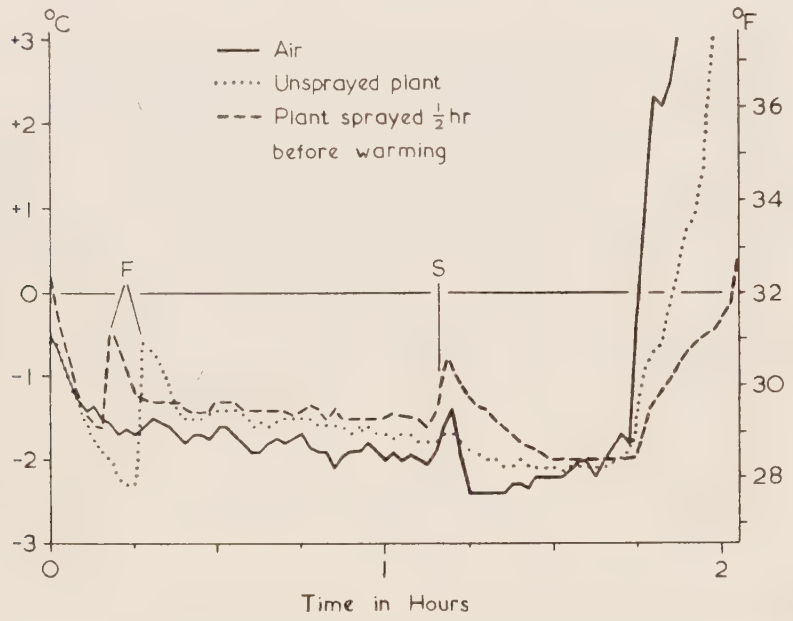

Fig. 1.

Effect of a single spraying with water on the temperature of a potato plant under frost conditions, compared with that of an unsprayed plant and of the air (Experiment 1). F=initial freezing of plant tissues. S=moment of spraying.

Plants in all treatments were severely damaged. The controls appeared to be the least affected, but the difference between treatments was not significant (Table I). The lack of a significant difference between the treatments may be attributed to the relative severity of the freezing conditions.

Table I.

Frost damage to potato plants.

Treatment.	Mean category of damage.*
Experiment 1.	
A. Plants sprayed half an hour before warming up	2·09
B. Plants sprayed immediately before warming up	1·14
C. Controls	1·06
Experiment 2.	
A. Plants sprayed half an hour before warming up	4·18
B. Plants sprayed immediately before warming up	4·25
C. Controls	3·93

(In experiment 1 the three treatments differ significantly as a group ($P=0·01$). The particular comparison between treatments B and C, however, was not significant ($P=0·05$). In experiment 2 the treatments did not differ significantly ($P=0·05$).)

* 0=no damage. 5=100 per cent damage.

Field trials.

Some experiments were carried out in the field on autumn-flowering plants of the strawberry Auchincruive Climax growing *in situ* or in pots, and on potato and tomato plants in pots. The temperature of the plants was measured by means of fine wire thermocouples inserted in several

flowers or stems of plants in each treatment. Temperature readings were taken with a potentiometer every ten minutes throughout the night, and every five minutes from the time of spraying. The damage was recorded about nine hours later.

Only one experiment (referred to as Experiment 3) will be described in detail.

Experiment 3.

Two treatments—(1) early morning spraying, and (2) control, were randomized in three blocks on strawberry plants growing in the field, each block consisting of four plots each containing three plants. The temperature of four flowers in each treatment was recorded.

The temperature of the air fell gradually from midnight until ten minutes before sunrise at 6.10 a.m. G.M.T., when a minimum of −2·9° C. (26·8° F.) was reached (Fig. 3). The treated plants were

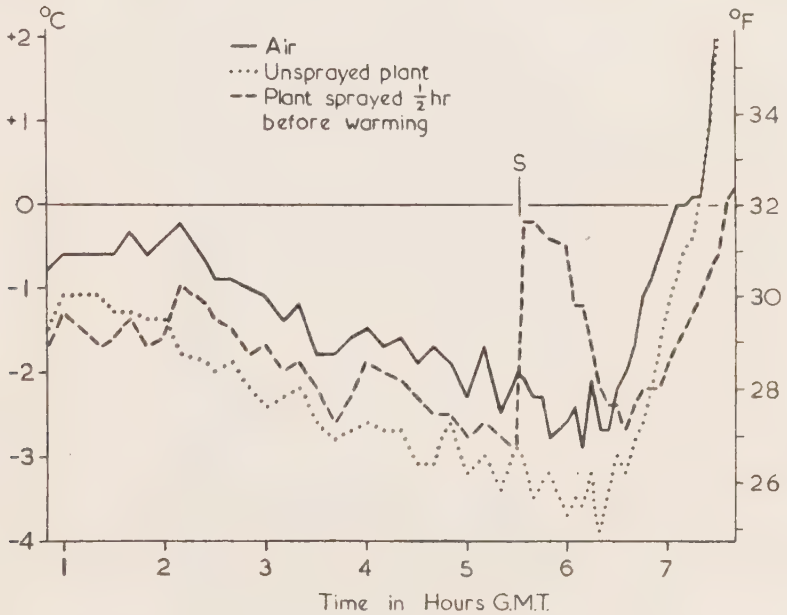

Fig. 3.

Effect of ' washing off ' hoar frost on the temperature of strawberry flowers under field conditions.
S = moment of spraying

each sprayed at 5.30 a.m. with about one litre of water at a temperature of 7·8° C. (46° F.). The air temperature at that time was fluctuating between −2·0° C. (28·4° F.) and −2·5° C. (27·5° F.), while that of the strawberry flowers was approximately −2·9° C. (26·8° F.). The spraying caused the temperature of the flower to rise rapidly to −0·2° C. (31·7° F.). After the water had frozen, the temperature of the flower gradually fell in one hour to −2·7° C. (27·1° F.), rising again when the sun appeared over the horizon. Meanwhile, the air temperature fell to −2·9° C. (26·8° F.) and that of the control flowers to −3·9° C. (25° F.).

The rate of thawing of the flowers varied according to their exposure to the sun. Flowers facing east thawed, on an average, twenty minutes before those facing west. Of the flowers facing east those sprayed with water, and thus covered with a thin layer of ice, thawed fifteen minutes later than the dry ones. There was less difference between the rate of thawing of sprayed and unsprayed flowers facing west.

There was significantly less damage to flowers on strawberry plants that had been sprayed than to those on plants that had not been sprayed (Table II). Also the damage to exposed flowers was about twice that to sheltered flowers regardless of the treatment—a contrast found on many occasions (unpublished records).

It should be noted that conditions were especially favourable in this experiment. The air was quite still, so that the heating effect of the water (equal to a precipitation of 2·5 mm. over the treated area) lasted for about 45 minutes. The air temperature after spraying was dangerously low for a short period only.

TABLE II.

FROST DAMAGE TO STRAWBERRY FLOWERS.

Treatment.	Percentage frost damage.	
	Exposed.	Sheltered.
Experiment 3.		
Plants sprayed in the morning	59·7	23·5
Controls	78·2	37·5

(Figures for treatments differ significantly ($P=0·05$). The effect of position is highly significant.)

In four other experiments there was no difference between the treatments. There were three reasons for this. In two of the experiments, tomato plants grown in pots, and Climax strawberries bearing autumn blossoms and growing in the field, were exposed to natural frost conditions. In both cases the temperature fell below the damaging level, killing the plants and flowers respectively, before the spray treatments were applied. In the third experiment tomato plants grown in pots were exposed to natural frost conditions. Unsprayed plants were compared with plants sprayed half an hour before sunrise, and at sunrise, respectively. With the exception of a few plants taken into the warmth of a caravan at the time of the first spraying, all the plants were killed. This showed that the first treatment was applied too soon, and the second one too late. In the fourth experiment potato plants, grown in pots, were exposed to natural frost conditions in the field giving a minimum air temperature of −2·0° C. (28·4° F.). No damage was recorded—showing that, for these potato plants, the damaging level was not reached.

Discussion.

It is clear that a single spraying of a plant during frost results in a temporary raising of the plant temperature, while the water freezes.

The effect of such a spraying will be harmful if, following the spraying, the plant temperature still sinks to the damaging level. The harmful effect is not due to the rapid warming up, as is shown by comparison of treatments B and C in Experiment 1, but to the freezing of the wet plant. Wet plants are, in fact, more liable to frost damage than dry ones, as many experiments have shown.

No beneficial effect will follow if (*a*) a damaging temperature occurs before spraying, (*b*) the temperature of both sprayed and unsprayed plants reaches a damaging level after spraying, or (*c*) if no damaging temperature occurs.

The effect will be beneficial if a damaging temperature has not occurred before spraying and the temporary rise of temperature, induced by the spray, is sufficient to keep the plant's temperature above the damaging level, even though the temperature of the air and of the unsprayed plants falls to, or below, this level. The amount and duration of the temperature rise will depend on how much water freezes on the leaves and on the ground, and also on the rate of air movement.

Thus, for early morning spraying to be of use, the following conditions must exist : (1) The spray must be applied before a damaging temperature is reached. (2) The temperature must fall after spraying to a point at which unsprayed plants will be damaged ; but (3) the frost must not be so severe or prolonged that the sprayed plants cool again to damaging point (which will be higher for them than for unsprayed plants).

In practice some indication as to the possible usefulness of ' washing off ' hoar frost can in each case be assessed by examining a minimum thermometer, or better still a thermograph chart, about half an hour before sunrise. If a damaging temperature has been reached earlier in the night or, if at the time of examination, it is clear that the temperature is not going to fall to a damaging level, spraying will be of no use. If, however, the temperature before sunrise is still falling and is likely to reach an injurious level, ' washing off ' hoar frost may be beneficial. A preliminary examination of thermograph records extending over some years shows that the proportion of frosts fulfilling these conditions is low. In general, therefore, morning ' washing off ' of hoar frost cannot be regarded as a reliable means of protection. It will usually have no effect, and sometimes may even be harmful.

The present series of studies did not include the possible effects of maintaining a high humidity, after a frost, on the recovery of a slightly damaged plant.

Acknowledgements.

I wish to thank Dr. W. S. Rogers, Mr. J. P. Ruxton, and Mr. C. H. W. Slater or help in this work.

Fig. 2.

Frost effects on potato plants exposed to −2·4° C. (27·7° F.); (1) not sprayed; (2) sprayed immediately before warming (3) sprayed half an hour before warming, showing greatest damage.

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Summary.

The effect of ' washing off ' hoar frost in the early morning has been investigated. Conflicting results have been explained on the basis of plant temperature measured by means of fine wire thermocouples.

Conditions are specified under which ' washing off ' the hoar frost may protect a plant from freezing, and others under which it may be ineffective or even harmful. In general this treatment cannot be regarded as a reliable means of protection against frost damage.

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NOTE ON A PLUM CAMBIUM MINER (AGROMYZIDÆ)

By N. R. LEE*

In April, 1952, brownish-orange vertical markings about 2 mm. wide were seen in the cambium of some six-year-old unworked plum rootstocks after the removal of areas of bark (Fig. 1) ; a dipterous larva was found at one end of each. Larvae were found mining both upwards and downwards. At some distance from the larva, each mine was separated from the cambium by newly formed wood ; transverse sections showed that it had developed into a ' pith fleck '. Such pith flecks have been recognized for more than a hundred years and, until early in the present century, were generally presumed to be a normal feature of some woods, e.g. alder and birch. Nielson (1906) concluded that they were, in fact, the occluded mines of insect larvae which had mined in the cambium. He considered *Agromyza carbonaria* Zett., which he had reared from pupae collected beside the base of an alder tree, to be responsible. Since that date, however, the larvae of ten closely related species of fly have been shown to cause pith flecks in various woods.

From a study of the literature it appears that there are two groups of Agromyzid cambium miners, viz. those which overwinter as pupae in the soil, e.g. *Dizygomyza barnesi* Hendel (Barnes, 1933), and those which winter in the tree in the larval stage. The second group comprises the two species, *D. pruni* Gros. from *Prunus domestica* L. and *P. avium* L. near New York (Grossenbacher, 1915), and *Dendromyza aucupariae* E. Kang. from *Sorbus aucuparia* L. in Finland (Kangas, 1948). Only one other described species, *Agromyza amelanchieris* Greene, infests a rosaceous host plant (*Amelanchier ovalis* Med.) ; this overwinters as pupae (Greene, 1917).

Pith fleck formation.

As a larva passes through the cambium it leaves a crescent-shaped hole (Fig. 3) which becomes occluded by proliferation of ray tissue (Fig. 4). This newly formed tissue remains confluent with its parent rays (Figs. 2 and 6) and probably functions as ray tissue. During the occluding process a replacement cambium forms on the outer side of the mine—in the incompletely differentiated phloem region. The new wood developed from this cambium causes the occluded mine to become embedded in wood tissues, where it remains as a permanent record of the infestation. The larva mines with its dorsiventral axis tangential to the stem and is furnished with a single apical hook-like tooth, with which it presumably attacks the radial walls of the cambial cells. Girdles of cuticular scales on its posterior segments assist in movement.

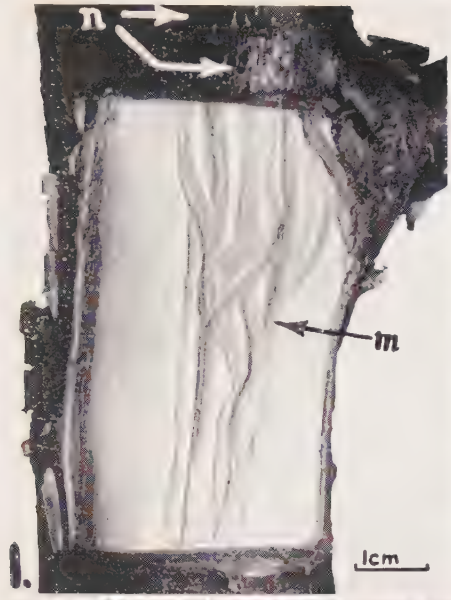
Pith flecks were found to vary considerably in size, small to medium flecks occurring in late wood and medium to large ones in early wood (Figs. 5 and 2). This relates to the life cycle of the fly, as described below.

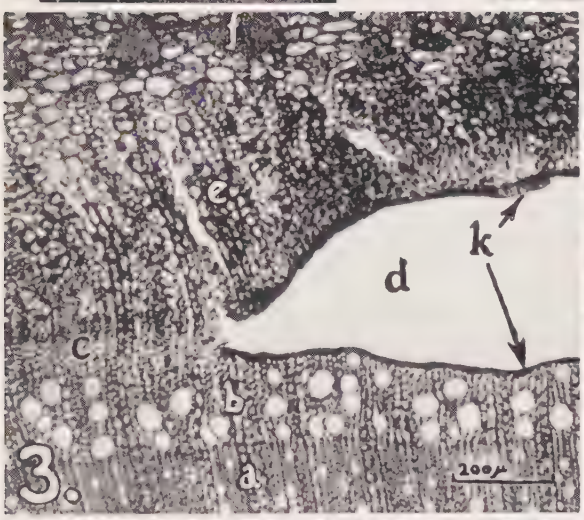
Life cycle.

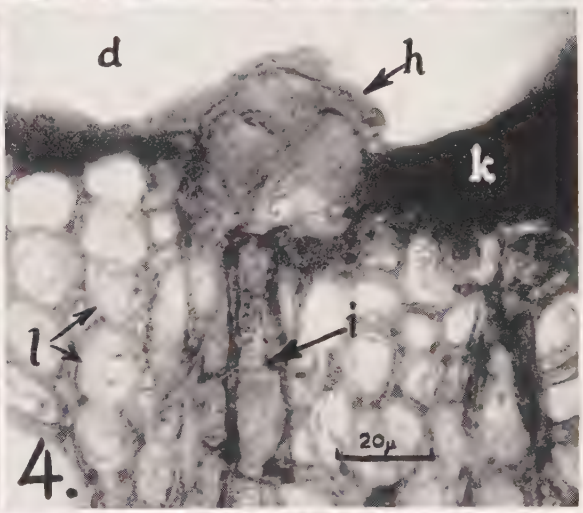
Early in August exit holes were found in the bark of infested trees from 25 to 100 cm. above ground level (Fig. 1). Between these exit holes and their related pith flecks, much wood and phloem had developed, while the exit holes had become surrounded by wound tissue (Fig. 2). At the same time larvae 3 mm. long were found in one- and two-year-old branches. In mid-September no larvae were found in one-year-old branches, and, although the rest of the tree was not examined—as this would kill it—it is obvious from sections of wood containing pith flecks that the larvae spend the winter in the tree. During May, larvae 15-18 mm. long were found in the lower parts of trees. It is therefore presumed that, between mid May and early August, the insects have left the tree, pupated, flown, mated, and laid eggs which have hatched. From the amount of wood development between related pith flecks and exit holes, it appeared that the larvae had left the trees in late May or early June (Fig. 2). The young larvae found in early August had mined a distance of more than a metre, from which it is estimated that the period from the pupation of one generation to the hatching of the eggs of the next is about four weeks, probably occurring during the month of June. The life histories of *Dizygomyza pruni* Gros. and *Dendromyza aucupariae* E. Kang. have been found to follow this general pattern.

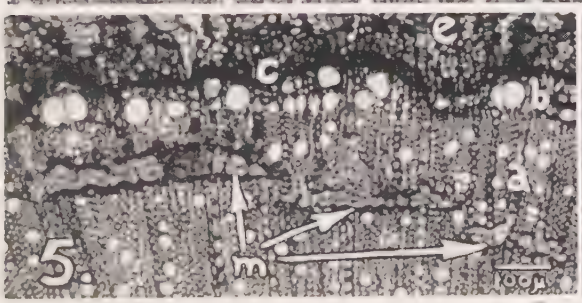
The species of this cambium miner has not yet been determined. Dr. E. Kangas, of Finland, to whom larvae were sent by the Entomology Section, states that, whilst they are *Dendromyza* larvae

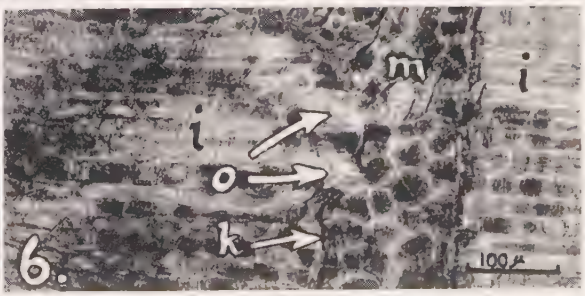
* A.R.C. Research Scholar, University of London, at East Malling Research Station 1950-1953.











Figs. 1-6.

1. Dissection of a branch of Myrobalan 29 in August, 1952, showing pith flecks and exit holes formed earlier in the year. 2. Transverse section of a similar branch showing exit hole and its related pith fleck. 3. Transverse section of a branch of Common Plum showing newly formed mine in May, 1952. 4. Similar section showing commencement of ray proliferation into a mine. 5. Similar section showing small flecks in late wood, increasing in size as the season advances. 6. Radial longitudinal section of trunk of Common Plum showing pith fleck and points of intrusion of ray tissue into the mine.

a=late wood, b=early wood, c=cambium, d=mine, e=phloem, f=phloem fibres, g=cortex, h=commencement of ray proliferation, i=ray, k=crushed cells forming mine-rim, l=incompletely differentiated wood fibres, m=pith fleck, n=exit hole, o=points of intrusion of ray into mine, p=wound tissue.

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closely related to *D. aucupariae* E. Kang., they undoubtedly belong to another species. Further work towards the identification of the species and confirmation of its life cycle is proceeding in the Entomology Section.

Distribution.

Pith flecks, fresh mines, and larvae have been observed in the following species and varieties : (*a*) *Prunus domestica* L., *P. insititia* L., *P. cerasifera* Ehrh., and the unworked plum rootstocks—Brompton, Brussels, Common Mussel, Common Plum, Pershore, Myrobalan B, and Myrobalan 29, all growing in the same location, and (*b*) Common Plum, Myrobalan 29, and suckers of an old damson tree growing in different locations. Mines have been seen in plum and cherry prunings and pith flecks in apple and quince.

Economic importance.

This insect would appear to have little direct effect upon tree growth ; young unworked trees of Myrobalan 29 known to be highly infested are growing well and appear healthy. In the plum budding season, when cambial disturbance may affect the percentage take, the larvae are either not yet present or are so small that they are of little consequence.

The proportion of fleck to normal wood is negligible in plum, and it is unlikely that the presence of flecks would lead to branch breakage. Brown (1913) and Peace (1952) discuss the limitations of pith-flecked timber, and their findings support this conclusion.

Other cambium miners have been associated with the spread of disease, e.g. a fungoid die-back of *Ribes* species (Grossenbacher, 1915) and a bacterial black canker of willow (Barnes, 1933). De Bary (1877) and Brown (1913) report gummosis spreading from pith flecks in *Prunus* species, which may have been due to Bacterial Canker. Such trees are susceptible to this disease from October to April (Wormald, 1931), a time when cambium miners are active, and it seems possible that the miners might assist in the spread of this disease within a tree—a process which is not fully understood. No gummosis has, however, been seen associated with pith flecks or mines in the present work.

Acknowledgements.

The writer wishes to thank Drs. A. B. Beakbane, A. M. Massee, and R. S. Pitcher for their assistance.

Summary.

A description is given of damage to young plum trees caused by the larva of an unidentified species of *Dendromyza* not previously recorded in the British Isles. The feeding of the larvae in the cambium causes mines which subsequently become occluded and form pith flecks in the wood ; the development of these pith flecks is described.

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WEATHER CONDITIONS DURING 1952

By A. P. PRESTON

The most notable features of the past year have been the dry early summer months, the wet August and autumn months, and an unusually wet and cool September.

Total rainfall for the year, 26·43 inches, was only 0·33 inches above the average ; the months of January, March, August, September, November, and December each had rainfall above the average, while February and July had unusually low rainfall. Although November was the wettest month of the year, rain was recorded on only 17 days but the amounts were relatively large ; the heaviest day's rainfall of the year, 1·13 inches, was recorded during this month.

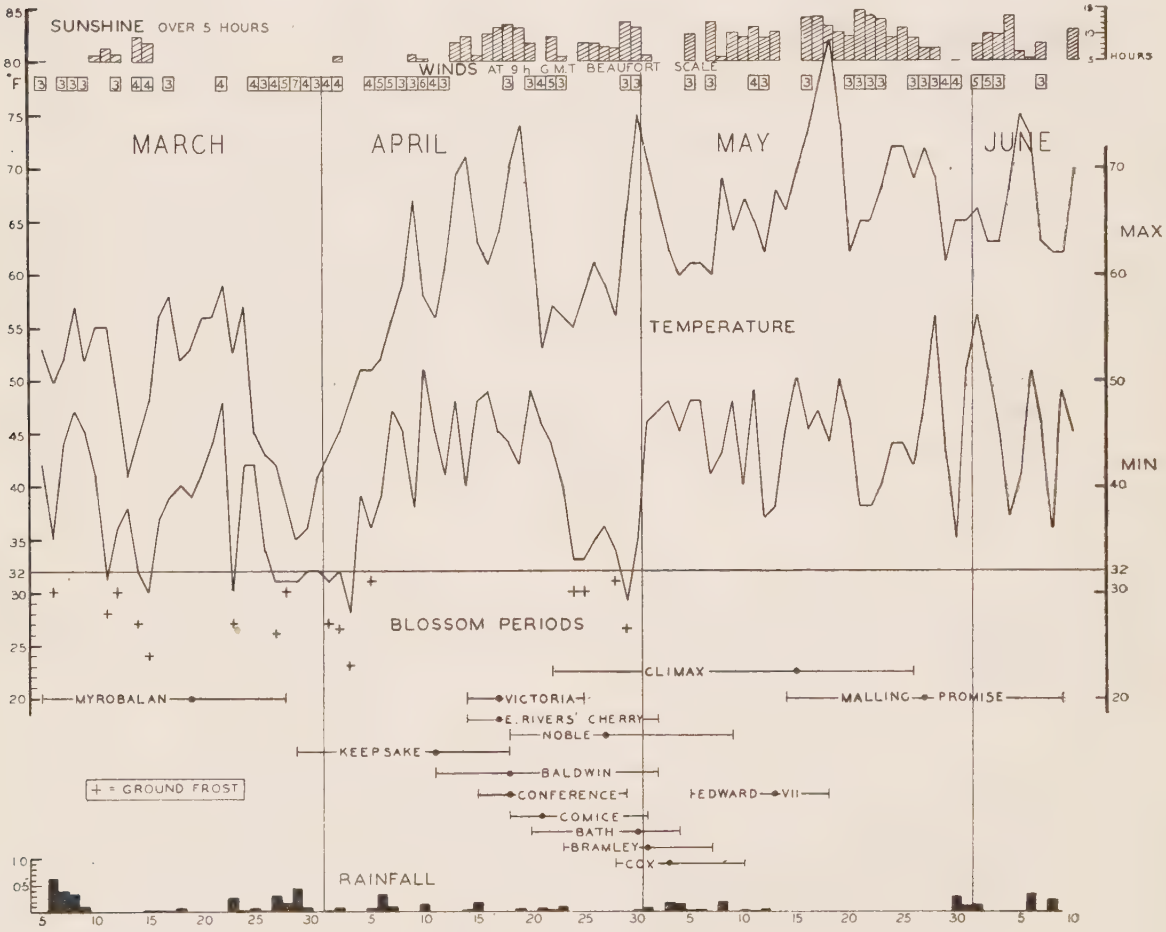


Diagram showing the weather recorded during the blossoming season, 1952.

Total sunshine during the year was 153 hours above the average, and only the months of February, March, August, and September had sunshine below the average. The sunniest day of the year was 30th June when 15·1 hours of sunshine were recorded.

Serious late spring frosts were again absent this year ; the lowest screen minimum temperatures during the main fruit blossoming periods were 28° F. and 29° F., recorded on 3rd and 29th April respectively. Ground frosts were more numerous than usual and the first autumn frost, on 19th September, was unusually early ; this frost damaged many outdoor tomato and cucumber plants.

East Malling.

Month.	Temperature in Screen.					Number of Ground Frosts.	Rainfall.			Sunshine.			Soil Temperatures.			
	Mean maximum.	Mean minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	35* years' average.	Total hours.	Average per day.	25 years' average.	4 inches.	8 inches.	2 feet.	4 feet.
January	43	32	55	16	37	16	2·30	0·36	1·96	84·7	2·7	47	36·4	37·3	40·3	43·5
February	42	30	51	24	36	22	0·83	0·23	1·85	66·0	2·3	68	34·6	35·4	37·7	40·3
March ..	50	37	59	30	43	9	3·27	0·63	2·01	90·7	2·9	123	42·4	42·4	43·8	43·5
April ..	59	40	75	28	49	6	1·06	0·31	1·65	193·4	6·4	152	49·3	48·1	48·3	46·5
May ..	67	44	82	35	55	0	1·02	0·29	1·67	250·9	8·1	200	59·9	58·3	57·5	53·4
June ..	70	48	88	36	59	0	1·15	0·34	2·04	253·0	8·4	222	63·5	61·6	61·2	57·6
July	72	53	88	41	62	0	0·67	0·31	2·19	222·1	7·2	208	67·4	66·4	66·2	62·0
August ..	70	54	77	44	62	0	2·85	0·61	2·19	187·4	6·0	194	63·1	62·5	63·6	61·8
September	60	43	72	30	51	3	3·20	0·91	1·98	142·1	4·7	147	53·2	53·8	57·5	58·5
October	55	40	61	27	47	6	2·60	0·43	3·11	108·3	3·5	105	46·5	47·0	50·2	52·5
November	44	33	55	18	38	16	4·64	1·13	2·79	60·5	2·0	55	38·1	39·6	44·0	47·9
December	42	31	52	22	36	17	2·84	0·51	2·66	57·5	1·9	42	34·7	36·0	38·7	41·9
Totals ..						95	26·43		26·10	1716·6		1563				

Sub-Station, Newlands Farm, Throwley.

January	42	32	51	21	37	20	2·47	0·37		94·7	3·1		36·9	37·7	41·1	41·7
February	41	31	49	23	36	21	1·17	0·34		78·4	2·7		35·0	35·6	38·0	41·5
March ..	47	38	57	29	42	10	3·50	0·83		94·5	3·0		41·8	42·4	43·2	43·3
April ..	57	41	73	29	49	10	1·26	0·49		192·6	6·4		47·1	47·0	46·5	45·4
May ..	64	46	79	39	55	2	1·03	0·33		255·9	8·3		57·8	57·0	54·9	50·9
June ..	68	50	85	43	59	0	1·09	0·27		246·3	8·2		61·5	60·5	59·1	55·2
July ..	71	54	84	46	62	0	0·69	0·42		235·2	7·6		65·9	65·2	63·7	59·2
August ..	69	54	75	48	61	0	4·25	1·14		198·9	6·4		62·0	62·1	62·3	59·9
September	59	45	71	35	52	2	4·65	1·34		139·7	4·7		53·8	54·9	57·6	58·1
October	54	42	59	33	48	6	2·74	0·77		116·4	3·8		47·6	48·4	51·0	53·3
November	43	34	54	24	38	15	4·44	1·18		72·5	2·4		39·1	40·6	45·0	49·2
December	42	32	51	26	37	14	3·70	0·58		65·6	2·1		35·3	36·3	39·2	43·4
Totals ..						100	30·99			1790·7						

* Weighted averages for the 35-year period 1881-1915, as used in the Monthly Weather Report of the Meteorological Office.

Mean screen temperatures were generally lower this year than last year. The highest screen temperature of the year, 88° F., was recorded on 30th June and 1st July.

Thunderstorms were recorded 5 times during the year, twice in May and August, and once in October ; local thunder was recorded on three other occasions.

Snow and sleet were recorded 29 times during the months of January-April inclusive, November and December. The ground was snow covered on 9 occasions, 3 times during January and March, once in November, and twice in December.

Newlands Farm, Throwley.

Rainfall recorded at this sub-station was 4·56 inches higher than that for East Malling ; the total sunshine was also higher by 74·1 hours. Although ground frosts were more frequent at Throwley, mean screen temperatures show the maxima to be lower than at East Malling and the minima higher.

Acknowledgements.

The writer wishes to thank Mr. G. F. Trowell for assistance during the year, and members of the Statistical Section who helped in computing the data and preparing the diagram. Mr. J. Cronk (by courtesy of T. Neame, Esq.) was responsible for records at Newlands Farm, and his co-operation is gratefully acknowledged.

STATISTICS

A REVIEW OF EXPERIMENTAL DESIGN AT EAST MALLING, 1948-1952

By S. C. PEARCE, G. M. JOLLY, and G. H. FREEMAN

Since the last review was published (Pearce and Hoblyn, 1948) field experimentation at East Malling has largely followed the recommendations given there, the great majority of trials being in randomized blocks, with or without split-plots. There have, however, been a number of developments, which it is the purpose of the present paper to discuss. It should be emphasized, however, that the lay-outs described here are needed only to meet special difficulties, and that the majority of designs used in practice are simple ones.

Some recent designs.

Calibration trials.

The ' Blank Trial for Future Experiments, 1945 ', described in the last review, has been the precursor of others, to which the name ' Calibration Trial ' has now been given (Pearce and Taylor, 1950). Later specimens have been designed in tiles rather than in stripes (Pearce and Taylor, 1950 ; Pearce, 1952), one of particular interest being that at the Efford Experimental Horticulture Station in which a quincunx plant was adopted together with the following tile of three varieties of apple :

C C

A B

C C

B A

Meanwhile earlier trials have been taken in for experimental purposes and have justified the hopes entertained of them, except in two cases where a few trees have developed abnormally and it is not clear how far the calibrating variates can be expected to forecast the future development of those trees. Even so, it is better that abnormalities should be discovered before the application of treatments rather than after.

Elimination of external guard rows.

Given a rectangular block of trees such that each headland is homogeneous, i.e. the consequences of a tree being on that headland are the same all the way along it, it is evident that a system of lay-out that takes account of the effects of rows and columns will eliminate the headland effects, provided that these do not interact with the effects of treatments. In this way, external guard rows are made redundant.

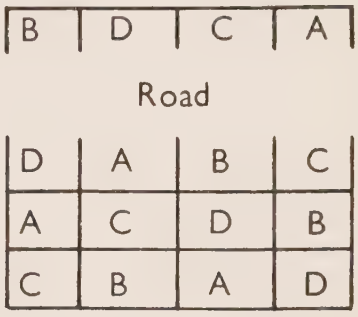
This approach has been used on a number of occasions, as, for example, in the Youden square* of strawberry varieties laid out at East Malling, as illustrated on the left-hand side of Fig. 1. The right-hand side of the same figure shows a Latin square designed for the Luddington Experimental Horticulture Station in which a farm road runs through the experiment, no guards being used alongside it.

* A brief description of this and similar designs may be helpful. If four treatments be allocated to four blocks, each of three plots, thus, I, ABC ; II, BCD ; III, ABD ; and IV, ACD, each treatment *occurs* an equal number of times (namely, three), and each pair of treatments *concurs* an equal number of times within blocks (namely, twice, A and B concurring in Blocks I and III, B and D in II and III and so on). Such a design is said to be in ' balanced incomplete blocks '. Where the treatments are balanced in respect of columns, each row containing a complete replicate, the design is said to be in a ' Youden square '.

The changing of treatments in a long-term trial.

From the point of view of trial design this is a generalization of the last, at least for the case where there is no likelihood of the new treatments interacting with the original ones. Fig. 2 shows three

Strawberries.
Letters A—K represent varieties. Each plot contains three plants.



Plums.
Letters A—D represent cultural treatments. Guards are indicated by lines. The experiment has sub-plots, but these are not shown.

FIG. 1.
Elimination of external guard rows.

stages of a trial designed to investigate means of controlling Fruit Tree Red Spider Mite and carried out at Writtle, Essex. It started with seven treatments, *A*, *B*, *C*, *D*, *E*, *F*, *G*, being compared in balanced incomplete blocks, this design being chosen on account of the awkward shape of the land available. Then a second set of treatments, *a*, *b*, *c*, *d*, was added in such a way that each occurred once in each block and once on each of the first treatments, which were discontinued though their residual effects remained. If a third stage had been required and if it had been certain that the residual effects of the first set of treatments had quite disappeared, a third set, α, β, γ, δ, could have been applied. Each would occur once in each block. Also, of the seven plots to receive one of the second treatments, four would receive a complete replicate of the third set and the others, three of the third set, balanced in relation to the second. Thus two plots of *a* were allocated to each of α, β and δ, two of *b* to each of β, γ and δ and so on. Alternatively, the third set could contain seven treatments arranged so that each occurred once on each of the second set and they were balanced with respect to blocks. It will be seen that this process could go on indefinitely, the trial being ready for a fresh set of treatments whenever the variation due to the residual effects of the last but one had become negligible.

Block	I	II	III	IV	V	VI	VII
Four plots to each block.	Fdδ Acα Dbβ Gaγ	Ecβ Faδ Cbγ Ddα	Bcα Edδ Daβ Gbγ	Abδ Bdα Eaβ Fcγ	Aaα Gdγ Ccβ Ebδ	Gcγ Fbα Cdβ Baδ	Dcδ Bbβ Adγ Caα

FIG. 2.
The changing of treatments in a long-term trial.
A, B, . . ., a, b, . . ., and α, β, . . . represent three sets of treatments applied in succession.

Other uses of balanced designs.

Apart from the uses of balancing already described, there has been a tendency to employ designs consisting of control plots occurring in each block, the other treatments being balanced in respect of blocks, as in the trials illustrated in Fig. 3. The left-hand side of this diagram shows a cover crop trial on apples at West Peckham, Kent, designed for the N.A.A.S., and the right-hand side a weedkiller trial at East Malling, the object of which was to find out which weedkillers harmed strawberries. In both, the aim was to compare the other treatments with the control rather than with one another, a task

for which these designs seem well fitted. The cover crop trial could well have been larger, but reliance was placed on the large plots to obtain reasonable sensitivity. The methods of analysis for designs in these last two sections can be derived from a general method published elsewhere (Pearce and Taylor, 1948 ; Pearce, 1953).

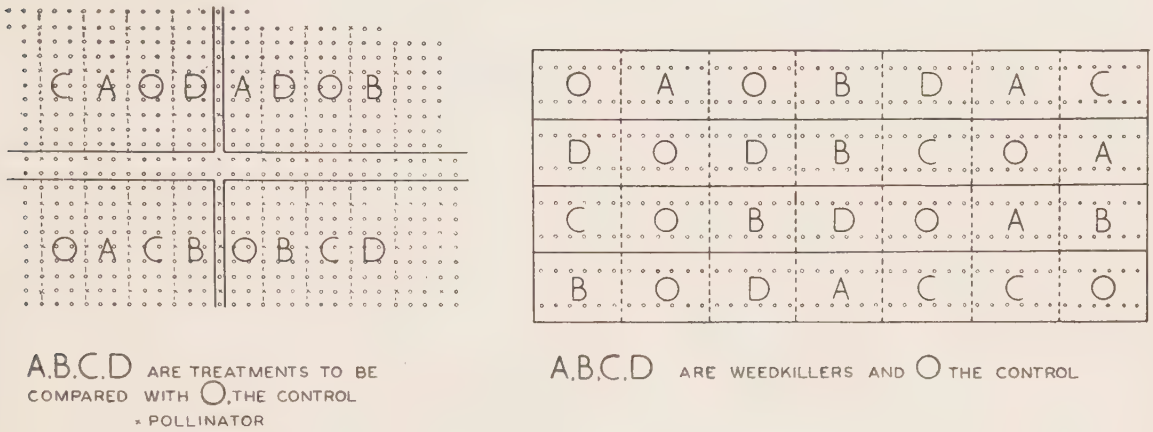

C A O D A D O B
O A C B O B C D
A.B.C.D ARE TREATMENTS TO BE COMPARED WITH O, THE CONTROL
* POLLINATOR
O A O B D A C
D O D B C O A
C O B D O A B
B O D A C C O
A.B.C.D ARE WEEDKILLERS AND O THE CONTROL

Fig. 3.

Examples of designs making use of balancing.

Left : Cover crop trial of apples. *Right :* Trial of weedkillers on strawberries.

Restricted randomization.

One problem that has now found at least a partial solution is the restriction of randomization so as to permit the subsequent thinning of a plantation or so as to prevent two given varieties being planted next to one another (Taylor, 1949). The solution already published is illustrated by a plum trial at East Malling shown in Fig. 4, the purpose of which was to investigate varietal frost susceptibility. This design is a development of one already described (' Apple Rootstock Trial, 1945 '—Pearce and Hoblyn, 1948). It could be expected that some degree of frost would occur while the trees were still young ; but, if it should be delayed until the trees were grown and needed thinning, half the trees could be removed to leave a smaller trial that would still suffice to show the larger differences in susceptibility. The method here is to confound the comparisons of varieties A-D with E-H between the temporary and permanent trees of Blocks I and II, and the comparison of varieties A, B, E, F with C, D, G, H similarly in Blocks III and IV. After thinning, the first comparison would be confounded between Blocks I and II and the second between Blocks III and IV.

I		II		III		IV	
E	**D**	A	**F**	G	**B**	E	**G**
B	H	**E**	B	**A**	H	**H**	A
G	**A**	C	**H**	C	**F**	B	**C**
C	F	**G**	D	**E**	D	**D**	F

Fig. 4.

Example of restricted randomization.

Bold type indicates a permanent tree.

A different method, not previously published, is illustrated in Fig. 5, which shows one example of a series of five raspberry variety trials to be planted at the Experimental Horticulture Stations at Luddington, Efford, Rosewarne, Fairfield, and Stockbridge House. In order to facilitate roguing it was desirable to keep varieties A and B apart but the method referred to in the last paragraph is

available only when the number of varieties is a multiple of four. Accordingly, a design was adopted akin to one in balanced incomplete blocks but with split-plots, the first and third sub-plots in each block forming one main plot and the second and fourth another, the varieties A and B being kept to the same main plot whenever they occur in the same block.

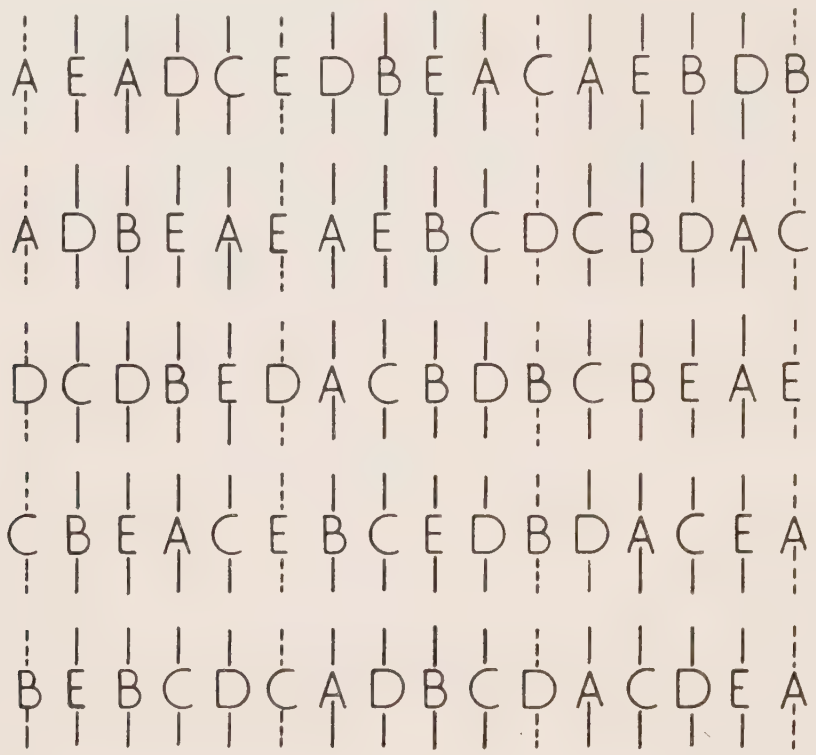

A E A D C E D B E A C A E B D B
A D B E A E A E B C D C B D A C
D C D B E D A C B D B C B E A E
C B E A C E B C E D B D A C E A
B E B C D C A D B C D A C D E A
A-E REPRESENT VARIETIES
EXPERIMENTAL ROW
GUARD ROW

Fig. 5.

Raspberry variety trial with restricted randomization.

Discussion.

There are several lines of thought apparent in these designs manifesting themselves differently as problems differ. One is to use devices such as balancing and confounding for achieving a lay-out that shall be economical of material and practicable in the field, rather than for reducing positional variation, that being their more usual function. With fruit trees, however, much of the variation is inherent in the trees and that due to position is of less relative importance as compared with most other crops, whereas the achievement of a design reasonable from the point of view of the farm is more difficult. Another is the increasing freedom in introducing complications now that more general methods are to hand for the analysis of data. Nevertheless, importance is still attached to simplicity of design and the majority of trials are in straightforward randomized blocks ; but, where special difficulties need to be overcome, to an ever-increasing extent a ready solution is available.

Summary.

Field trials recently designed at East Malling are reviewed with statistical comments.

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PLANT PHYSIOLOGY

THE ASSAY OF GROWTH SUBSTANCES BY A MODIFIED STRAIGHT GROWTH METHOD

By C. R. HANCOCK* and H. W. B. BARLOW

The study of growth substances in the apple shoot has so far been confined to an estimate of the *net* auxin/inhibitor status as determined by transport into agar (Hatcher, 1948) or by examination of ether extracts incorporated directly into agar.

These studies do not distinguish between a balance resulting from large amounts of both auxin and inhibitor and one resulting from small amounts, nor can the presence of an inhibitor be demonstrated in an extract which promotes growth (or vice versa).

The present work was undertaken in an attempt to examine in more detail the auxin and inhibitor status of woody shoots in relation to their growth and to the part played by growth substances in abscission. For both purposes it is necessary to separate the growth promoting and the growth inhibiting substances in the plant organ being studied, and recent use of paper chromatography for this purpose (Bennet-Clark *et al.*, 1952 ; Luckwill, 1952) led to its adoption here.

The modified Avena curvature test which has previously been used in this laboratory for the examination of diffusates and ether extracts (Rawes and Hatcher, 1949) is not ideal for the estimation of growth substances separated on a paper chromatogram, mainly because inhibitors cannot be assayed directly. The straight growth of coleoptile sections is better adapted for this purpose, and in using the technique described by Bentley (1950), a modification was introduced, which has provided a very simple assay method of particular suitability for extracts which may contain growth promoting and inhibiting substances in various mixtures. Another advantage is that the test is sensitive over a wider range of growth substance concentrations than the curvature test.

Methods and results.

Modifications of the Avena straight growth technique.

The experimental procedure of earlier workers was revised by Bentley (1950) to provide a much simplified technique capable of giving consistent results ; this was achieved by selecting coleoptiles at a particular stage, using single 1 cm. sections from each coleoptile, and eliminating the ' food factor ' from the test solution. The technique, however, involves the tedious operation of threading the coleoptile sections on to glass capillaries, while the volume of test solution required is relatively high. The modifications described here were made to overcome these two disadvantages.

By using dishes of 4 cm. diameter, growth of the sections was as good in 1 ml. as in 5 ml. (Fig. 1, curves a and b), while, by using small specimen tubes 2 in. long and $\frac{3}{8}$ in. diameter containing five coleoptile sections, it was possible to reduce the solution volume to 0·5 ml. without detrimental effect (Fig. 1, curves d and e). If the sections are not threaded on capillaries, it is found that after remaining in dishes or tubes of solution for 24 hours they have been geotropically stimulated and are considerably curved, making measurement difficult. This tendency was eliminated by rotating the tubes about their long axes by attaching them to a horizontal drum turning twice an hour.

It will be seen that a logarithmic relationship exists in all cases between the concentration of the growth substance (3-indolylacetic acid, referred to as IAA) and the percentage elongation of the sections between the limits of 0·01 and 1 p.p.m. There is, however, considerably greater growth when the sections are rotated, both in water and in all IAA concentrations. This effect is of value, since it provides a wider range over which inhibitors can operate (i.e. 12 per cent in dishes, 26 per cent in tubes).

The reason for the increased elongation obtained when the sections are rotated is still obscure, although some factors have been investigated. One is the presence of the leaf in the unthreaded sections, which is pushed out when threading on to capillaries ; this may contribute some factor causing increased growth. Data from an experiment to test this hypothesis are presented in Table I.

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TABLE I.

PERCENTAGE ELONGATION OF COLEOPTILE SECTIONS WITH AND WITHOUT THE LEAF.

Concentration of IAA p.p.m.	Leaf left *in situ*.	Leaf removed.	Leaf removed but added to solution.
0	37	27	29
0·01	42	39	40
0·1	68	58	53
1	84	67	57

It is apparent from these results that it is only when the leaf is left *in situ* that better growth occurs, which suggests either that the leaf produces a substance which is able to stimulate the coleoptile only when there is close contact between the two, or that the coleoptile is injured by threading it on to a capillary. The absence of injury, however, is not the sole benefit of rotation, as is shown by the increased growth made by sections threaded on to capillaries and rotated in tubes (Fig. 1, c).

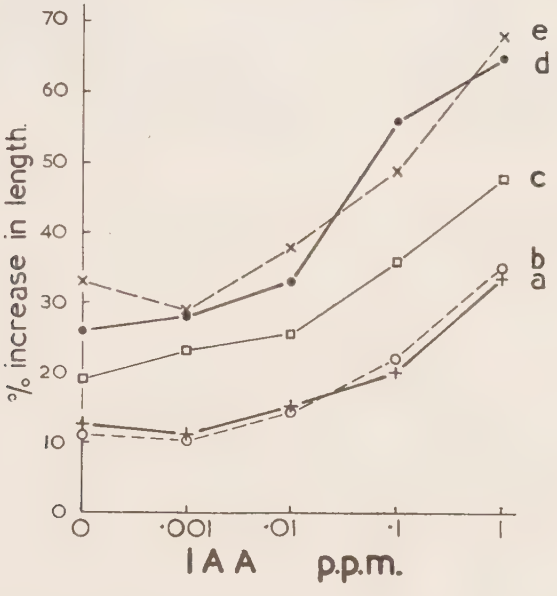

FIG. 1.

Percentage increase in length in 24 hours of Avena coleoptile sections in solutions of IAA at various concentrations. Initial length of sections 1 cm. The following conditions were maintained: (i) In dishes, sections threaded on capillaries, (*a*) with 1 ml. solution, (*b*) with 5 ml. These were not significantly different. (ii) In rotated tubes, (*c*) on capillaries with 1 ml. solution. Significantly different from rest. (iii) In rotated tubes, sections not threaded on capillaries, (*d*) with 0·5 ml. and (*e*) with 1 ml. solution. These treatments did not differ significantly.

In the apparatus described by Steward, Caplin, and Millar (1952) for mass tissue culture, in which the speed of rotation is much higher (1 r.p.m.), the alternate exposure to air and immersion in the liquid medium was found to be very effective in promoting growth, and aeration was suggested as an important factor. Preliminary experiments in which air was bubbled through solutions in stationary tubes did not suggest that aeration is the most important factor in causing the increased growth of sections in rotated tubes.

Chromatography.

Using the descending method, paper chromatograms were run with a partition solvent of *iso*-propanol, *n*-butanol, water, and ammonia solution (0·88 sp. gr.) in the proportions of 50 : 50 : 10 : 10. The tank used could accommodate four papers, each 22 cm. wide with a running distance of 37 cm. The papers were left in the tank in solvent vapour for an hour or more to equilibrate before solvent was added to the troughs. Under these conditions the solvent front traversed the paper in about 17 hours, allowing chromatograms to be run safely overnight.

After running a paper to which 4γ or more IAA has been applied, the IAA spot can be located by spraying the dried paper with the following reagent (slightly modified from Bennet-Clark *et al.*, 1952) : 5 volumes 20 per cent perchloric acid, 1 volume 1 per cent ferric chloride, 6 volumes ethanol. On warming a pink spot appears.

Using the growth test to detect IAA on run chromatograms much smaller amounts can be located, and, although the colour reagent indicated reasonably localized IAA spots, considerable lateral spread across the paper was revealed by the more sensitive test. To overcome this the paper was slit into 10 strips from 2 cm. behind the starting line to the free edge, the strips being 2 cm. wide with a 2 mm. gap between them.

Assay method.

The material to be assayed for growth substances was cut into small pieces and extracted with peroxide-free ether for 24 hours at about 2° C. in a refrigerator. The extract was separated into acid and neutral fractions by the technique of Larsen (1949), evaporated down to a small volume and applied to the starting line of the chromatogram paper. After running as described, the papers were dried at room temperature, and, as a routine procedure, were examined under ultra-violet light ; the distance between the starting line and the solvent front was divided into 10 (occasionally 20) segments, which were placed in tubes with distilled water together with 5 coleoptile sections. As the segments of paper absorbed about 0·25 ml. of water, 0·75 ml. was added to the tube to leave 0·5 ml. free solution for the test sections.

Since either the paper itself or persistent traces of solvent might affect the growth of the sections, preliminary tests were made with blank paper before and after treating it in the standard manner for a chromatogram. Table II shows these comparisons for a range of IAA concentrations.

TABLE II.

PERCENTAGE INCREASE IN LENGTH OF COLEOPTILE SECTIONS AFTER 24 HOURS.

Concentration of IAA, p.p.m.	Without paper.	With untreated paper.	With paper treated as for chromatogram.
0	35	25	27
0·01	37	24	27
0·1	52	44	51
1	78	57	65

In view of the marked inhibition of growth of the sections by the paper, whether it had been run as a chromatogram or not, the routine assay procedure includes water and a range of IAA controls with blank paper which has been run as a chromatogram.

Results with synthetic 3-indolylacetic acid.

Table III shows the distribution of growth promoting activity in successive segments of four chromatograms to which 0·04 ml. of a 10 p.p.m. solution of IAA had been applied (0·4γ).

TABLE III.

DIFFERENCES BETWEEN PERCENTAGE INCREASE IN LENGTH OF TEST AND CONTROL SECTIONS.

Paper and strip No.	Segment of paper.									
	1	2	3	4	5	6	7	8	9	10
75 Strip 1 ..	−3	0	23	7	−1	4	2	−2	−2	−4
,, 10 ..	−9	1	26	−3	1	1	8	6	−1	−2
76 Strip 1 ..	5	32	12	2	1	−1	7	1	4	−5
,, 10 ..	5	30	14	4	−8	−7	2	−3	−5	−1

Papers 75 and 76 were run on different occasions, and there was some variation in the R_F for IAA, although the two strips on either paper agreed closely. Constant conditions were not maintained, and, while the usual R_F is about 0·35, variation has been observed from 0·2 to 0·45. This variation can now be partly reduced, but not entirely, and therefore ' marker spots ' of IAA are run on the outside strips of each chromatogram, either for chemical or biological detection of the IAA position.

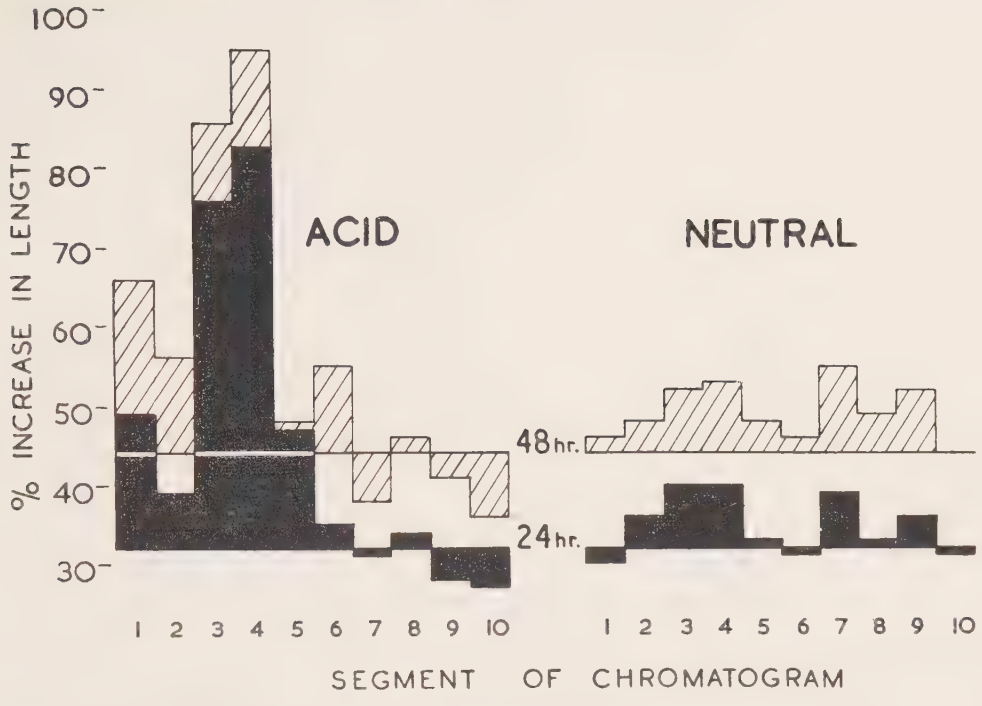

FIG. 2.

Average percentage increase in length of test sections in the presence of successive tenths of the chromatogram paper (starting line to the left) to which acid and neutral fractions of an IAA solution had been applied. The level of growth of the water controls forms the base line of the histograms : solid, after 24 hours growth ; shaded, after 48 hours.

To check the efficiency of the technique for separating an extract into acid and neutral fractions, a relatively large amount (unmeasured) of IAA was treated as an ether extract. Fig 2 shows, as would be expected, that activity was confined to the acid fraction. In this experiment the sections were measured after 24 hours in the rotating tubes, and again after an additional 24 hours ; during this second period further growth has taken place, in contrast to sections in dishes which do not extend appreciably after 24 hours. The general pattern of response is the same, however, and only 24 hours results are considered below.

Results with plant extracts.

Shoots from stoolbeds of the apple rootstock Crab C have been extensively examined in this laboratory for growth promoting and inhibiting substances (Hatcher, unpublished), their long unbranched main stem being convenient for such studies. This material, therefore, was chosen for the preparation of the following ether extracts : (*a*) stem ' tips ', i.e. the apex and all leaves which had not unfolded ; (*b*) leaves 1 and 2, which were unfolded but not much expanded ; (*c*) leaves 7 and 8, which were just ' mature ' ; (*d*) leaves 15 and 16, which were about half way down the shoot when the sample was taken in mid-September. The internodes below each leaf were also extracted. Duplicate extracts were prepared, each of two shoots.

The results of assaying the acid and neutral fractions of the leaf extracts are presented in Fig. 3, which shows the following features.

The acid fractions show growth promoting activity in the IAA position, marked in the tip, less in leaves 1 and 2, and absent lower down the shoot. These same trends are shown by an inhibitor of higher R_F (0·45-0·65). In the older leaves two other growth promoters appear, one near the solvent front (R_F 0·75-0·95) in leaves 7 and 8 and leaves 15 and 16, the other near the starting line (R_F 0·05-0·15) only found in the lowest leaves on this occasion.

Examination of the acid fractions of the internode extracts gave indications of all three growth promoters in the younger parts of the stem but probably no activity lower down (internodes 15 and 16).

The neutral fractions of the leaf extracts contained most of the pigments and other substances extractable by ether, and these clogged the paper and caused very slow running and poor separation.

It is thought that this material may have caused the general inhibition shown over much of the paper, particularly as where there was least pigmentation there was often least widespread inhibition ;

e.g. in the lightly coloured tip extract inhibition was limited to the middle regions of the chromatogram, and in leaves 1 and 2 the unpigmented region near the solvent front gave some growth promotion. Leaves 15 and 16, however, although there was considerable coloured matter present, showed no inhibition. The neutral fractions of the internode extracts were relatively free from these pigments and ran satisfactorily. Internodes 1 and 2 showed regions of promotion near the starting line and the solvent front separated by an inhibiting region, as in the neutral tip extract. The lower internodes showed very little activity at all.

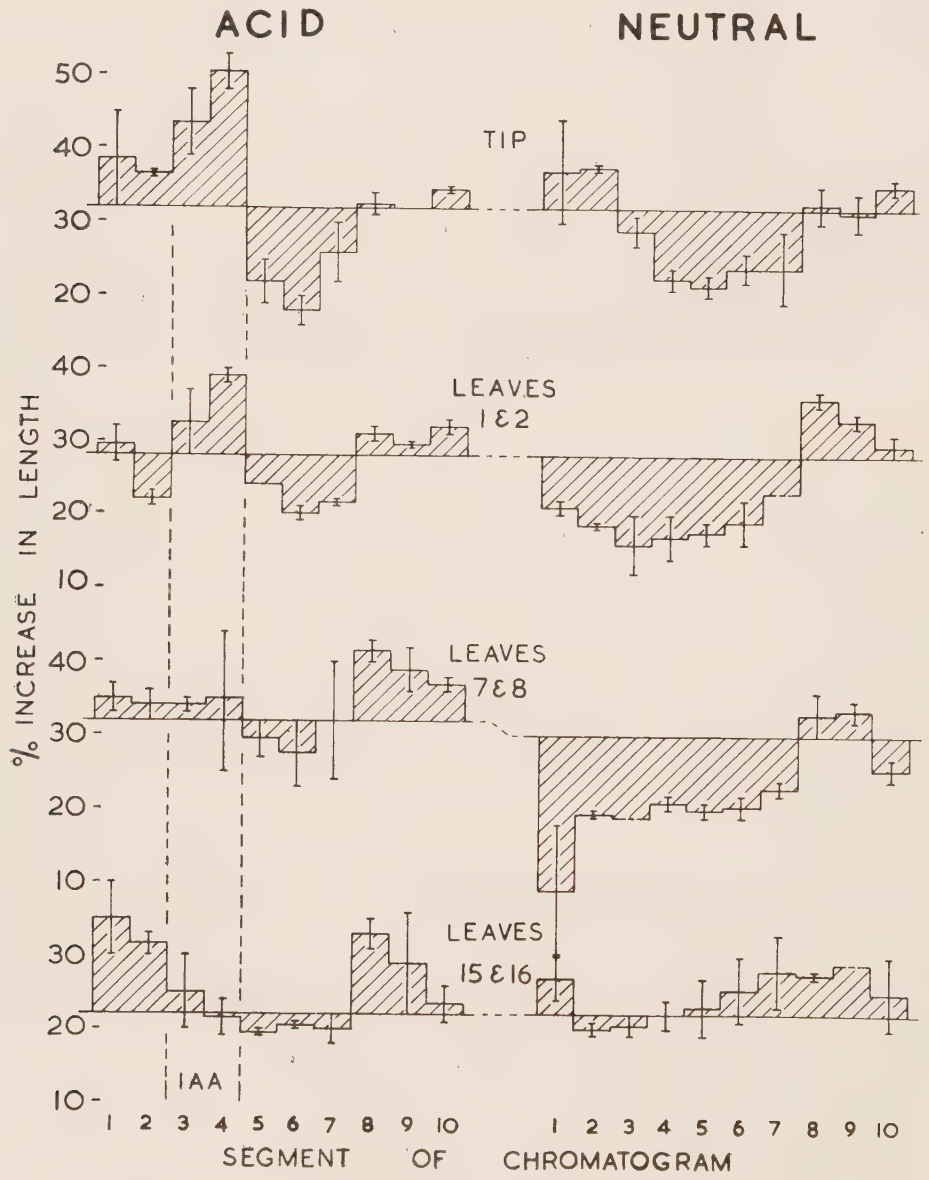

FIG. 3.

Average percentage increase in length of test sections in the presence of successive tenths of the chromatogram paper, to which acid and neutral fractions of ether extracts of shoot tips and certain leaves of the apple rootstock Crab C had been applied. Actual values of the duplicates are indicated by the vertical lines. The IAA position in this series of tests was in the third and fourth tenths.

Discussion.

The general picture obtained from these assays of Crab C shoot material is as follows. In the tip there is marked growth promoting activity due to an acid substance with an R_F similar to that of IAA ;

in the leaves this falls off with age, but is succeeded lower down by acid growth promoters with R_F values of about 0·1 and 0·8. From the results reported here it seems likely that an acid inhibitor with an R_F of about 0·55 is associated with the promoter in the IAA position ; as the promoting activity falls off, so does the inhibition.

In the stem similar promoting and inhibiting substances were found, but were not so clearly separated in time.

Neutral growth substances were less easily demonstrated, but it is probable that two promoting and at least one inhibiting substances are present in Crab C leaf and stem.

It should be pointed out that these extracts were made late in the season, and a subsequent sample taken in October showed very little activity in any part of the shoot. It is highly probable that the pattern of growth promoters and inhibitors changes during the season, as does the net auxin status (Hatcher, 1948) ; this will be investigated.

A comparison of these results with those obtained by other authors for other plant materials is made in Table IV.

TABLE IV.

APPROXIMATE R_F VALUES OF GROWTH PROMOTERS AND INHIBITORS IN VARIOUS PLANT EXTRACTS.

Material.	Promoter.	Inhibitor.	Author.
Ether extracts of Crab C tip and young leaves	0·3 (acid)*	0·55 (acid)	Present paper.
Ether extracts of Crab C mature leaves	0·1 (acid) 0·8 (acid) 0·8 (neutral) ?	Widespread in neutral fraction down to R_F 0·7	Present paper.
Etiolated sunflower seedlings	0·25 (acid)*	0·35 (acid)	Bennet-Clark *et al.* (1952).
Pear, swelling fruit buds Apple, endosperm Grape, developing seeds Tomato, stamens Tomato, stem tips	0·8	0·65	Luckwill (1952).
Asparagus, unripe fruits	0·35*	0·15 0·65	Luckwill (1952).
Broccoli, young leaves	0·35* 0·8	0·65	Luckwill (1952).

* IAA position for the respective test.

Linser's results (1951) are difficult to compare with the others, as he used adsorption chromatography on columns of aluminium oxide, etc., but he obtained from brussels sprouts and from lilac leaves a substance which was almost certainly IAA, a second promoter and an inhibitor.

Allowing for the different solvents used in the chromatography of these extracts, it seems that, over a wide range of plant material, only a limited number of growth promoting and inhibiting substances have so far been found : (1) an acid promoter which is probably 3-indolylacetic acid, two others with (2) lower and (3) higher R_F values, and probably two neutral promoters with (4) a low and (5) a high R_F value respectively ; (6) a single acid inhibitor seems to be present in all the extracts, and (7) there may be another with a low R_F (Luckwill, 1952). (8) There is at least one neutral inhibitor.

Two of these growth promoters may eventually prove to be 3-indolylacetaldehyde and 3-indolylacetonitrile (Bentley and Housley, 1952), and the others may well be allied substances ; the possible nature of the inhibitors, however, has not yet been suggested.

Summary.

A modified straight growth technique is described in which Avena coleoptile sections are contained with small volumes of solutions in specimen tubes ; these are rotated on a horizontal axis to prevent geotropic curvature of the sections. Under these conditions growth is greater than in the usual method in which sections are threaded on capillaries and floated on solutions in dishes.

This technique is applied to the estimation of growth substances separated from plant extracts by paper chromatography, the methods of which are described.

In the acid fraction of the extract, a growth promoting substance which appears to be 3-indolylacetic acid, and an inhibiting substance, are present in very young apple leaves (Crab C rootstock), while two other promoters are present in the older leaves. The neutral fraction shows widespread inhibition, which may be due to pigments and other solids present in this fraction. Where these do not occur in great quantity there are indications of two growth promoting substances.

Growth promoting and inhibiting substances similar to those in the leaves are found in extracts of internodes.

The growth substances shown here to be present in Crab C leaves and stems would appear to correspond with those recorded by other workers in various plant materials.

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A METHOD OF GROWING TREES WITH THEIR ROOTS IN A NUTRIENT MIST

By M. C. VYVYAN and G. F. TROWELL

When investigating the effect of internal factors on plant growth, such as rootstock varieties, it is necessary to eliminate, as far as possible, the effects of uncontrolled variation in nutritional conditions. Some soil variability is almost inevitable and is normally met by the use of randomized blocks or other statistical devices, but these have certain limitations when plants of widely different rates of growth or habit are being examined. No matter how uniform the soil may be, trees with genetically different growth rates, habits, or mineral requirements, may exhaust the soil around them to different degrees, and thus impose on the soil a variability related to the treatments under examination. It is true that the effects of such a bias may be regarded, in a sense, as part of the effects of the treatments, since the bias results from them, but these effects are secondary and are best eliminated when examining the primary effects of the treatments. An additional danger of growing root systems of different vigour in the soil is that there is differential competition between them ; this can only be countered by very wide spacing and consequent waste of land.

Variability in nutritional conditions can be reduced by growing plants in water culture, a method recently very fully reviewed by Hewitt (1952), since the constitution of the solution bathing the roots can be kept under much stricter control. This method has the further advantage that the plants can be weighed at intervals without suffering damage. It is not sufficient, however, to supply identical solutions to every tree at fixed intervals : they must be kept identical. Pearse (1940) grew trees of Cox's Orange Pippin on M.IX and M.XII in water culture and determined the uptake of the various nutrient elements by periodical analysis of samples of the residual solutions. He found that initially identical solutions became in a fortnight widely different in concentration and composition, according to the rootstock. Such induced differences might be controlled by frequent changes of the solution, or—where exact composition is of little importance so long as it is the same for all—by frequent or continuous intermingling of the solutions ; this would require the movement of relatively large quantities of fluid. An alternative method, requiring less fluid, consists in supplying the nutrients to the root in the form of a spray or mist. Pearse (1937) tried this method and found it had advantages, in particular, the roots were more nearly normal than in water cultures. Barker (1922) had already succeeded in growing apple trees with their roots in a spray, and the method has also been used by Carter (1942) for pineapples, and by Klotz (1944).

The development of a suitable technique for growing apple trees in spray culture was started in 1951 ; the method evolved seems of sufficient interest to warrant this brief progress report.

There are two types of chamber : a large one that will take several trees, and a small one for single trees.

The large chambers.

These are 12 ft. long, 4 ft. wide and 3 ft. high (Fig. 1) and constructed of breeze blocks, coated with cement, on a concrete floor. The floor slopes from the sides to the centre, where there is a longitudinal channel that slopes from the ends towards the mid-point ; a lateral channel leads from this point, through an outlet at the side of the chamber, to the feed tank ; the top of this can be seen in the centre of Fig. 1. Three coats of black bitumastic paint were used to waterproof the walls and floor and to prevent the cement from contaminating the solution.

The chamber has a sectional pent roof made of panels of laminated plastic board. As at present arranged, there are two rows of ten trees supported on a framework of metal pipes which run longitudinally above the beds. The stems of the trees pass into the chamber through holes in the roof ; each tree can be readily removed by opening the appropriate panel.

The atomizers.

Each atomizer (Fig. 2) consists of two blowlamp nipples (A) ; one to supply the solution, the other the air. They are cemented together with a synthetic resin (Araldite) as shown (C) after roughening the surfaces. A short length (approx. 5 mm.) of stainless steel tubing (B) (external diameter 0·9 mm.), such as is used in the manufacture of hypodermic needles, is inserted into the solution nipple so that its free end is exactly over the centre of the hole in the air nipple ; it is then

cemented in position. The bases of the two nipples are mounted in polythene tubes (D). The whole structure can be strengthened by heating two short lengths of thin glass rod and inserting these between the polythene tubes. These rods are not shown in the figure.

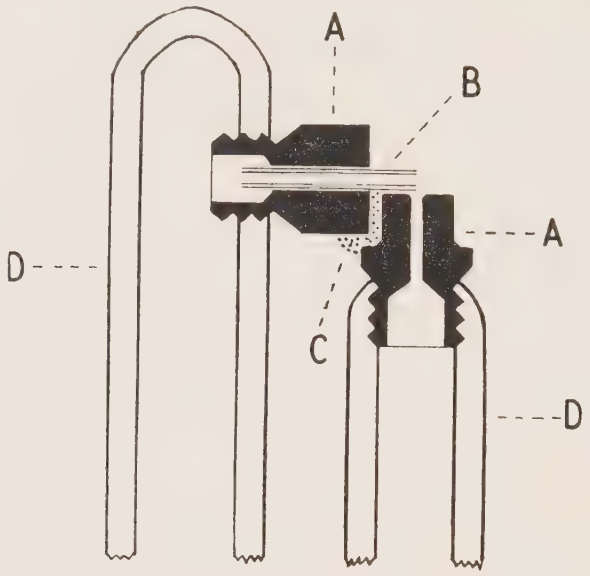

FIG. 2.

Sectional diagram of atomizer.

A=Blowlamp nipples. B=0·9 mm. stainless steel tube. C=Synthetic resin adhesive. D=Polythene tubes.

Five such atomizers are fitted along the centre line of the chamber (Fig. 3), one below each group of four trees. As the fine spray fills the chamber with a more or less uniform mist, the effect of variability between atomizers is largely eliminated. The air and solution nipples are connected by polythene T-pieces to the air and solution lines of plastic garden hose.

The air pressure for operating these atomizers, about 8 lb. per sq. in., is provided by a diaphragm pump ; as this uses no oil, filters between it and the atomizers are unnecessary, but the air entering from the atmosphere is filtered. This filter, about 8 ft. from the ground, and the pump housing, are on the right in Fig. 1.

Feed tank and solution filter.

Most of the solution makes its way back, via the central channel, to the feed tank, whence it is sucked up once more by the atomizers and re-used. This circulating system has proved very economical over long periods. The amount of solution in the tank and channel is kept at 100 litres ; loss to the trees or by evaporation is made good by topping up at intervals or by an automatic feed. The solution is filtered before it returns to the atomizers to prevent these becoming choked by particles of dirt or root washed from the chamber. The filter is made from a $2\frac{1}{2}$ in. plastic butter dish with a screw top. A $\frac{7}{16}$-in. hole, drilled at the bottom of the dish, is connected to a polythene tube of the same diameter by two perspex nuts. This tube leads to the solution line and the atomizers. The filtering agent is a piece of ordinary nylon stocking stretched across the top of the dish, and held in position by the screw top, which is perforated with a number of $\frac{1}{8}$-in. holes. This type of filter proved better than one of glass wool, small particles of which tend to get into the atomizers and clog the small steel tubes. Particles of dirt that pass through the nylon are too small to cause any trouble.

To prevent freezing, low voltage heating wires are installed in the tank and channel and connected with a 15-V. transformer. The wires are covered with plastic tube to prevent leakage or contamination of the solution. The current is only turned on when freezing is likely.

Single-tree chamber.

This consists of two main parts (Fig. 4) : a base formed of a cast concrete block (A), 13 in. × 13 in. × 4 in., with a central tapering well, and a length of ordinary brick flue lining (B), which stands in a recess on the block and forms the walls. A single atomizer (C) of the type already described, enters

through a rubber bung in a hole at the bottom of the well. The air line (D) from this leads to the air pump, and the solution line (E), protected by a small filter, to a small feed tank (G). The mist that condenses on the roots and the wall runs back through a narrow glass-lined outlet into the tube (F) and so into the tank. The level of the solution in the tank (G) is kept constant by the device (H). The tree is supported by canes (J) fitted into holes in the concrete block. The stem of the tree passes through a hole in the plastic roof (I). A considerable number of these chambers can be run off the same air pump and each can have its own tank and culture solution, or if several trees are to have the same solution, they can have a common feed tank.

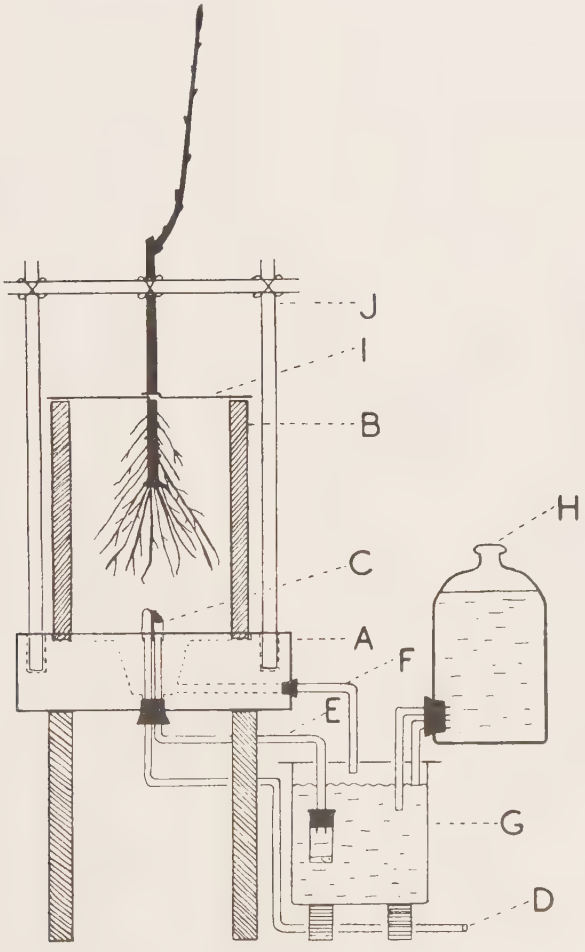

FIG. 4.

Single-tree chamber.

A=Concrete block. B=Brick flue lining. C=Atomizer. D=Air line. E=Solution line and filter. F=Outlet tube. G=Feed tank. H=Constant level device. I=Plastic roof. J=Cane supports.

Summary.

A method is described for growing trees with their roots in a fine mist of nutrient solution. The mist is produced by atomizers working on the scent-spray principle. The mist condenses and runs back into the tank, thus the solution circulates without passing through a pump.

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Fig. 1.

Large chamber. Pump house and air intake filter on right, with feed tank in centre.

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FIG. 3.

Interior of large chamber with some roof panels removed, showing atomizers with pipe lines in position, and root development on apple rootstock

SOME EFFECTS OF THE ADDITION OF CARBON DIOXIDE TO SOIL OF POT CULTURES OF MALLING V APPLE ROOTSTOCKS

By B. D. BOLAS and H. C. RUCK*

There is a considerable conflict of evidence regarding the effect of carbon dioxide content of the soil air on the growth of plants. Parker (1925) concluded that carbon dioxide was not an important factor in the absorption of inorganic nutrients by plants, whereas Hoagland (1944) and Chang and Loomis (1945) found that high concentrations of carbon dioxide resulted in restricted uptake both of nutrients and water by the roots. On the other hand, Livingston and Beall (1934) found a marked increase in vigour of six different species of plants on passing carbon dioxide through the soil of pot cultures.

Many other examples of contradictory evidence could be given. Page and Bodman (1951) pointed out that, when carbon dioxide is high in the soil air, oxygen tends to be deficient, and it is possible that any observed effect may be due to either too high a concentration of carbon dioxide or too low a concentration of oxygen, or to the effect of the interaction of the two gases on growth. (Erickson, 1946 ; Leonard and Pinckard, 1946). Apart from the possibility of a deficiency of oxygen which has been shown to reduce absorption of ions by the roots of the plant, increased carbon dioxide may have an indirect effect by altering the pH of the soil, and thus influencing both the availability of nutrients and the microflora. There also remains the possibility of increased carbon dioxide uptake by the roots, the carbon dioxide becoming available in the leaves for photosynthesis (Livingston and Beall, 1934).

It has long been known that the maximum carbon dioxide level and minimum oxygen level in soil air for normal growth vary greatly for different plants (Hoagland, 1944).

Some results of increasing the soil carbon dioxide in pot cultures of Malling V apple rootstocks are given in this paper.

Materials and methods.

At the beginning of March, 1952, 200 one-year-old Malling V clonal rootstocks were cut to 1 ft. in height, and weighed individually.

120 of these plants were selected for uniformity of weight and planted on the 18th March, 1952, in John Innes potting compost No. 1 in 10-inch pots, there being 6 stocks per pot. These plants were grown in a small glass shelter with open sides. Half of the pots, selected at random, received carbon dioxide from a cylinder at the rate of about half a litre per minute for three minutes in the morning, and three minutes in the evening daily. The gas was passed into the soil and precautions taken against any chilling effect. The remaining pots were kept as controls. A representative sample of the stocks was taken at the time of planting for determination of dry weight and ash weight. The regression of dry weight and ash weight on fresh weight was determined and was used for estimating the initial status of each plant. The carbon dioxide treatment was begun on the 15th May.

By the middle of May, 48 of the plants were still dormant. These were allowed to remain in the pots but were not included in subsequent measurements. The shoots were reduced to one per plant on the 13th May. The leaves from the surplus shoots were measured (length and breadth) and leaf prints taken. These data were used to establish the relationship between ' cross-products ' and true leaf areas at the beginning of the experiment.

Growth measurements.

Measurements of length and breadth of leaves were made at 14-day intervals from 15th May to 17th September, 1952, when the measurements were terminated. On 30th September the plants were divided into leaves, stems, and roots ; fresh and dry weights were determined for each portion and a representative sample kept for ash determination. A sample of leaves was again printed and the relationship between ' cross-products ' and leaf areas determined.

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Carbon dioxide determinations.

Successive carbon dioxide determinations of the soil air were made with a Haldane apparatus on one pot in each treatment. The results are given in Table I.

TABLE I.

PERCENTAGE CONCENTRATION OF CO_2 BY VOLUME IN SOIL AIR AT DIFFERENT TIMES.

High CO_2.	Control.	Time in hours after passage of CO_2.
69·0	0·04	nil
26·0	0·17	1
7·2	0·07	2
1·1	0·17	3
0·38	0·11	4
0·30	0·17	5
0·20	not taken	6
0·10	0·20	15

The standard error of a single observation as derived from the control series was ±0·06.

It will be seen that a high concentration of carbon dioxide was attained immediately after passing the gas, but that within an hour the concentration had fallen to approximately one-third of its original value, the difference between the two series becoming progressively less with time. Previous work (Bolas and Ruck, 1949) has shown that even higher temporary concentrations of carbon dioxide produced no injurious effect on the roots or shoots or reduction in tuber number of potato plants, although dry weight of tubers was reduced by 60 per cent. The use of similar concentrations of carbon dioxide with apples did not, therefore, appear unduly hazardous.

Hydrogen ion determinations.

pH determinations of the soil were made at the beginning and end of the experiment by means of the glass electrode. On the 19th May, four days after the commencement of the carbon dioxide treatment, samples were taken from the middle of the soil mass of every pot. The mean values with their standard deviations and number of observations (n) were as follows :—

High CO_2 6·79±·057 ($n=11$) Controls 6·99±·042 ($n=12$)

By this time the carbon dioxide had already produced a significant effect ($P<·01$) on soil pH, the high carbon dioxide soils being more acid. Final samples taken in a similar manner at the end of the experimental period (30th September) showed that both soils had now become significantly more alkaline. The mean values were as follows :—

High CO_2 7·14±·105 ($n=10$) Controls 7·87±·084 ($n=10$)

The increase in alkalinity of the controls was significantly greater ($P<·001$) than that of the high carbon dioxide series. Thus it appears that the carbon dioxide treatment has counteracted the drift to alkalinity of the soil.

Results of experiments.

Dry weight determinations.

The mean initial dry weights (g.) of the plants in both treatments as calculated from the regression line, and the final weights as determined experimentally, are given below :—

High CO_2.		Controls.	
Initial dry weight (estimated).	Final dry weight.	Initial dry weight (estimated).	Final dry weight.
5·98±0·05 ($n=24$)	22·80±2·37	5·76±0·05 ($n=26$)	40·64±1·98

There was a highly significant difference between the treatments ($P<·001$), the control plants having a much greater dry weight. The actual dry weights (g.) and the dry weights of the leaves, stems, and roots, expressed as a percentage of the whole plant, are as follows :—

	High CO_2.			Controls.		
	Leaves.	Stems.	Roots.	Leaves.	Stems.	Roots.
Actual weights ..	5·54 ±0·59	15·44 ± 1·37	3·24 ±0·46	6·87 ±0·51	25·93 ± 0·89	9·32 ±0·44
Percentage of total dry weight ..	24·3	61·4	14·2	16·8	60·1	22·9

The greatest effect of the treatment was in the reduction of root weight, the experimental roots being only about one-third of the controls, the difference being highly significant ($P<\cdot001$). The tips of the treated roots were clubbed (Fig. 1) while the development of tissues from the cambium opposite to the primary xylem groups was retarded, particularly in the case of the large rays. This resulted in the production of a vascular cylinder which was lobed in outline (Fig. 2). In treated roots rapid growth took place in the region of the pericycle opposite to the protoxylem groups and the form of the root as a whole was almost circular, and not lobed, in outline.

The stems of the high carbon dioxide plants also weighed significantly less ($P<\cdot001$), being about half the weight of the controls.

No significant difference was found between the dry weights of the leaves in the treatments.

The leaf areas were calculated at fortnightly intervals by means of 'cross-products' (length $\times$ breadth), and relationship between the 'cross-products' and true leaf area estimated by two regression lines—(1) $y=7\cdot8+0\cdot692x$ for initial sample (S.E. of single observation 4·6 per cent), and (2) $y=1\cdot6+0\cdot603x$ (S.E. of single observation 8·6 per cent) for all remaining samples. No significant difference was found for the regression lines between treatments.

The mean leaf areas calculated in this manner over the experimental period are given in Table II.

TABLE II.

MEAN LEAF AREA (CM^2) THROUGHOUT EXPERIMENTAL PERIOD.

Date.	14th May.	28th May.	11th June.	25th June.	9th July.	23rd July.	6th Aug.	20th Aug.	3rd Sept.	17th Sept.
High CO_2	72	142	222	272	334	400	462	525	551	535
Controls	80	176	318	487	615	716	737	758	770	737

The mean leaf area of the control plants at the end of the experimental period was significantly greater ($P<\cdot001$) than that of the treated plants. It is of interest to note that, although there is a highly significant difference in leaf areas between treatments, there is no significant difference in leaf dry weights. Thus, the dry weight per unit area of the high carbon dioxide leaves must be greater than that of the control leaves. The mean dry weight of the leaves per square cm. at the end of the experiment in the high carbon dioxide treatment was $10\cdot14$ mg. $\pm0\cdot24$ ($n=24$) and in the control $9\cdot08\pm0\cdot21$ ($n=26$), the difference being significant ($P<\cdot01$).

The mean water contents of the plants and their parts expressed as grams of water per 1 gram of dry matter are as follows :—

	High CO_2.	Controls.	*Significance.*
Whole plant	$1\cdot71\pm0\cdot060$	$1\cdot64\pm0\cdot048$	*n.s.*
Leaf	$1\cdot46\pm0\cdot018$	$1\cdot58\pm0\cdot020$	($P<\cdot001$)
Stem	$1\cdot08\pm0\cdot053$	$0\cdot95\pm0\cdot041$	*n.s.*
Root	$3\cdot77\pm0\cdot105$	$3\cdot26\pm0\cdot105$	($P<\cdot001$)

It will be seen that there is significantly less water in the leaves of plants receiving carbon dioxide, whereas in the roots there is significantly more. This may indicate that there is either a failure of the assimilate from the leaves to reach the roots, or of the water from the roots to reach the leaves. The fact that there is no significant difference in water content of the experimental and control plants suggests that there is no harmful effect of carbon dioxide on water uptake by the roots.

Net assimilation rate.

The mean leaf area of each plant was determined by integration of all the values over the experimental period, and the net assimilation rate, as measured by increase in dry weight of whole plant (mg.) per square cm. of leaf surface per day, was calculated. The results were :

High CO_2 $0\cdot322\pm0\cdot025$ ($n=24$) Controls $0\cdot477\pm0\cdot057$ ($n=26$)

The treated plants show a significant lower assimilation rate per unit leaf area ($P<\cdot02$), thus there is no indication that carbon dioxide uptake of the roots has any beneficial effect on assimilation.

Ash weights.

Six plants were chosen from each treatment and representative samples of leaves, stems, and roots were ashed at 500° C. in a muffle furnace. The ash weights of the plants and their parts are given in Table III.

TABLE III.

ASH WEIGHTS (G.) AT BEGINNING AND END OF EXPERIMENT.

Treatment.	Initial weight of stem.	Final weight.			
		Leaves.	Stem.	Root.	Total.
High CO_2	0·168 ±0·013	0·566 ±0·032	0·661 ±0·225	0·210 ±0·025	1·445 ±0·026
Controls	0·136 ±0·012 ($n=6$)	0·630 ±0·120	0·815 ±0·095 ($n=6$)	0·390 ±0·022	1·689 ±0·145
Significance	*n.s.*	*n.s.*	*n.s.*	*Sig.* ($P<·001$)	*n.s.*

It will be seen that except in the roots there is no significant difference in the mineral content in the two treatments. If, however, the mineral uptake per unit dry weight of root is calculated a highly significant difference between treatments is found, the uptake in the high carbon dioxide plants being much greater. The following values were obtained ($n=6$) :—

Uptake of mineral matter (g.) per g. dry weight of root. High CO_2—0·350±0·011. Controls 0·150±0·018 ($P<·001$).

Chemical analysis of leaves.

The first observed effect of the treatment was the appearance of a distinct chlorosis in the apical leaves of the high carbon dioxide plants on 10th June. This chlorosis gradually became less marked and at the end of the experiment there was no apparent difference in leaf colour between treatments. The control plants did not show any such chlorosis. Interveinal injections of iron, manganese, copper, zinc, nickel, boron, nitrogen, phosphorus, potassium, magnesium, and calcium were carried out and a marked response for iron was obtained in the high carbon dioxide plants. All other results were negative. On the 16th June the fifth leaf from the apex of each plant was removed. These leaves were divided into two groups—high carbon dioxide and controls, and five random samples of five leaves each taken from each treatment. The leaves were both cleaned and analysed according to the technique of Mason (1953), five replicate analyses being made in each case. The results are shown in Table IV.

TABLE IV.

LEAF ANALYSIS—CONCENTRATION OF ELEMENTS EXPRESSED AS PERCENTAGE DRY WEIGHT, WITH EXCEPTION OF MN AND FE EXPRESSED IN PARTS PER MILLION.

Treatment.	Mg.	Fe.	Ca.	K.	P.	N.	Mn.
High CO_2 ..	0·304 ±0·0117	36 ±2·63	0·80 ±0·031	1·90 ±0·091	0·146 ±0·0038	2·53 ±0·101	178 ±6·36
Controls ..	0·268 ±0·0117	68 ±5·21	0·71 ±0·019	1·72 ±0·055	0·181 ±0·0022	3·28 ±0·032	147 ±5·58
Significance ..	*n.s.*	*Sig.* ($P<·001$)	*Sig.* ($P<·001$)	*n.s.*	*Sig.* ($P<·001$)	*Sig.* ($P<·001$)	*Sig.* ($P<·01$)

It will be observed that the high carbon dioxide treatment has reduced the concentrations of iron, phosphorus, and nitrogen and increased that of manganese and calcium in the leaves.

Discussion.

An outstanding effect of the carbon dioxide treatment is the reduction in root growth, the roots being only about one-third of the dry weight of the controls. Stem weight is reduced to one half, but there is no significant difference in leaf weight. The marked decrease in weight of the roots may possibly be due to either (1) the direct effect of soil carbon dioxide on root development, or (2) a reduction in translocation of assimilates to the root in the high carbon dioxide plants.

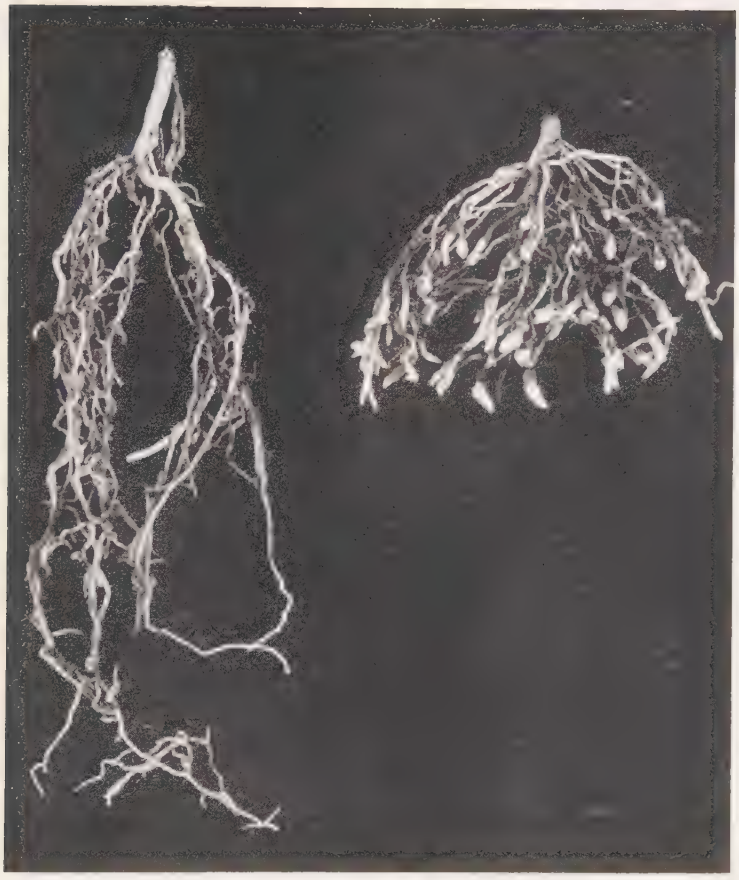
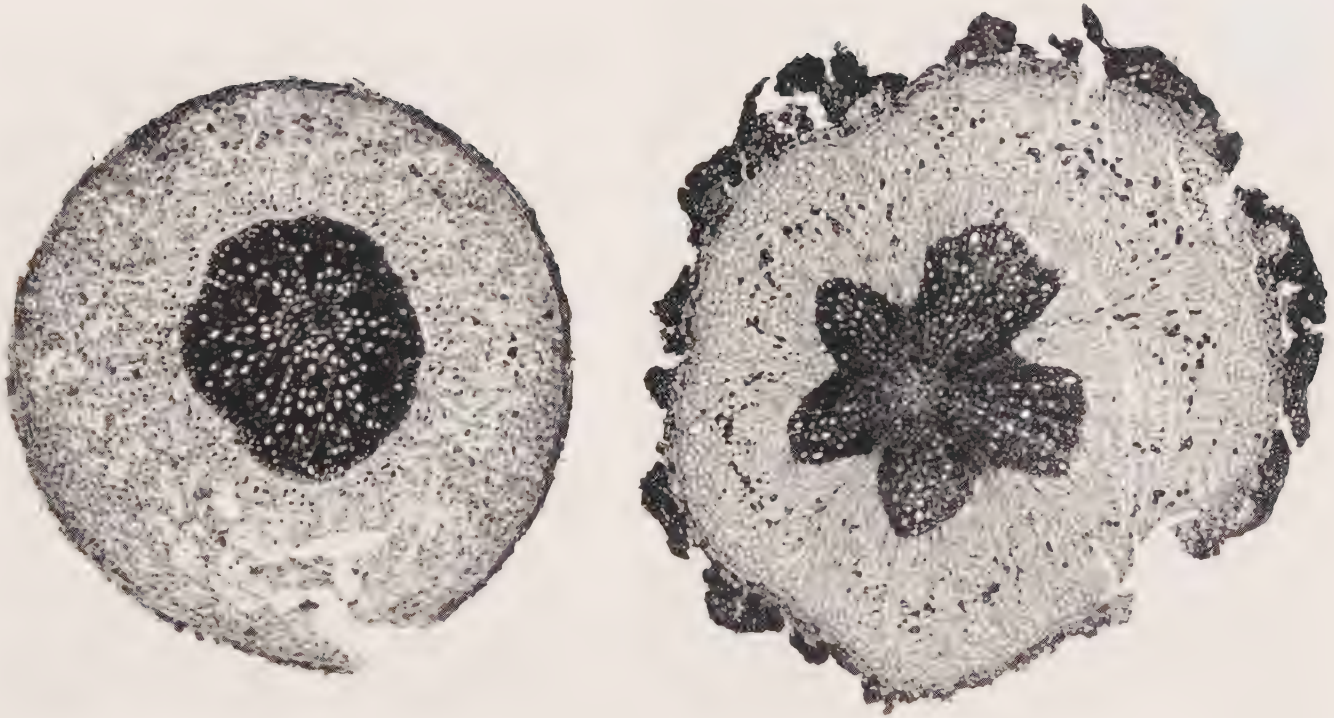


Fig. 1.

Roots of M.V. apple rootstocks. Control (left) and high carbon dioxide (right).



Control.

High carbon dioxide.

FIG. 2.

Transverse sections of roots of M.V. apple rootstocks.

Although there is a considerable modification of root structure in the high carbon dioxide plants, the amount of mineral matter absorbed per unit of root weight is much greater than in the controls, and on this basis the root appears to be more efficient. There is thus no evidence for a direct toxic effect of the added carbon dioxide on total mineral uptake.

There is, however, a much lower concentration of iron, nitrogen and phosphorus in the leaves of the treated plants leading to a chlorosis during the early stages of growth which may have adversely affected carbon assimilation.

In spite of the fact that the net assimilation rate of the treated plants is significantly lower, there is no significant difference in dry weight of the leaves. Thus an additional effect of the high carbon dioxide may be to reduce translocation of assimilates from the leaf, either by reduction of phloem activity, or by the reduced concentration of certain elements, e.g. iron, phosphorus, or nitrogen, which may partially inhibit the conversion of assimilates into labile forms.

The water content of the leaves of the high carbon dioxide plants was significantly less, whereas that of the roots was significantly greater. This may be explained either by the reduced translocation of assimilates from the leaves, or reduced movement of water from the roots.

Further evidence, indicating an effect of carbon dioxide in reducing translocation in the potato, was obtained by the authors. In a similar experiment, although the number of tubers formed in the high carbon dioxide plants was the same as in the controls, the total dry weight of the tubers was reduced by 60 per cent.

In conclusion, it would appear that the major effect of high carbon dioxide is to reduce the movement of substances within the plant.

Acknowledgements.

Our thanks are due to Professor F. G. Gregory by whose authority the work was carried out ; to Dr. F. R. Tubbs for facilities at East Malling Research Station ; to Mr. A. C. Mason for the loan of apparatus and help in other ways ; to Dr. S. C. Pearce and his staff for help and advice in the planning and statistical treatment ; to Dr. A. B. Beakbane for anatomical studies of the roots ; and to Miss A. V. Delap for leaf injections.

Summary.

Malling V apple rootstocks were grown in compost in 10-inch pots. In one series carbon dioxide was passed into the soil. The treated plants were smaller, net assimilation was reduced, leaf area was less, the leaves had less water per gram of dry matter and the roots more, and the concentration of certain elements in the leaves was lower. The root/shoot ratio was less, and changes in root structure were found. Mineral absorption per unit of root weight was increased.

No indication of a direct toxic effect of carbon dioxide on root growth was found, the evidence suggesting that the main effect of additional soil carbon dioxide was to reduce the movement of materials within the plant.

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BIOCHEMISTRY

THE CLEANING OF LEAVES PRIOR TO ANALYSIS

By A. C. MASON

Although the problem of the removal of surface contamination from leaves, prior to analysis for mineral constituents, has engaged the attention of most workers in this field, there still remains doubt as to how this may be accomplished without loss by leaching from the tissues (Goodall and Gregory, 1947).

Following upon the work of Jacobson (1945), Smith, Reuther and Specht (1950) examined several cleaning methods for citrus leaves and concluded that scrubbing in detergent or dilute acid is necessary to remove iron contamination. However, they did not show experimentally that removal of iron during washing was not due to leaching, nor did they show how the washing procedure affected the estimation of other elements. Leaching over much longer periods than is necessary for cleaning has been studied by Mann and Wallace (1925).

Comparison of methods for cleaning apple leaves.

Thirty samples of leaves were collected from five neighbouring trees of Ellison's Orange on 9th October, 1951, and each of the following treatments was replicated six times : both sides of the leaf were wiped with (*a*) dry muslin or (*b*) wet muslin ; the leaf was scrubbed with a soft nylon toothbrush for 10 seconds while immersed either in (*c*) water, (*d*) 0·3 *N* hydrochloric acid or (*e*) 0·2 per cent 'Teepol'. After the scrubbing treatments the leaves were rinsed in running tap water, then twice with distilled water, the excess water shaken off, and the leaves air-dried for a few minutes. After cleaning by each of these methods the petioles and midribs were removed and the laminae dried, ground, and analysed for potassium, calcium, and iron by methods described elsewhere (Mason, 1950, 1951, 1952).

TABLE I.

EFFECT OF CLEANING TREATMENT ON THE RESULTS OF CHEMICAL ANALYSIS.

Treatment.	Iron, p.p.m.		Potassium and calcium.
	Mean of 6 replicates.*	Standard deviation.	
Wiped with			
(*a*) dry muslin	160	20·0	
(*b*) wet muslin	150	18·9	
Scrubbed with			No significant differences ($P=0·01$)
(*c*) water	113	5·3	
(*d*) 0·3 *N* HCl	107	2·9	
(*e*) 0·2% Teepol	108	7·4	

* A difference between means of 15 p.p.m. is significant ($P=0·01$). Figures bracketed together are not significantly different.

It can be seen from Table I that the treatments had no significant ($P=0·01$) effect on the content of potassium or calcium, but the analyses for iron indicate that scrubbing not only led to significant reduction in the amount present, but also very materially increased precision. This latter effect was substantial and equivalent to what might be expected from an increase in sample number by some sixteen-fold ; it also provides clear evidence that the degree of contamination from leaf to leaf cannot be regarded as uniform.

Further experiments were carried out to determine whether the iron removed from the leaves by the scrubbing treatments is due to dust on the surface of the leaves or whether it is leached from the plant cells.

Analysis of atmospheric dust.

Dust, collected from the vertical glass surfaces of a greenhouse in the vicinity of the trees, was shown to consist mainly of silica with 3·5 per cent of iron, 0·03 per cent of manganese, and a little organic matter. It may be calculated that the difference of approximately 50 p.p.m. of iron between the wiping and scrubbing treatments could be due to a deposit of 0·3 mg. of this fine dust per leaf. This amount of dust would increase the manganese content by only 0·5 p.p.m.

Analysis of apple leaves protected from dust contamination.

Leaf buds on plants growing in the field and in the greenhouse were covered with cellophane bags in the spring and the leaves allowed to develop continuously protected from dust. Analyses of washed and unwashed leaves were made for N, P, K, Ca, Mg, Mn, and Fe (Tables II and III, samples 1, 2, and 3).

TABLE II.

EFFECT OF WASHING ON THE IRON CONTENT OF LEAVES GROWN IN THE PRESENCE AND ABSENCE OF DUST (SINGLE SAMPLES).

Sample.	Date, 1952.	Cultural conditions.	Variety.	Treatment.*	Iron content p.p.m.	
					Covered.	Uncovered.
1	7th May	Field	Apple rootstock M.VII	Washed in HCl	115	137
				Unwashed	127	214
2	21st May	Greenhouse	King of Pippins	Washed in 'Teepol'	108	100
				Unwashed	110	254
3	30th May	Greenhouse	Worcester Pearmain	Washed in 'Teepol'	90	138
				Unwashed	96	250
4	30th May	Field (see text)	Apple rootstock M.VII	Washed in 'Teepol'	74	98
				Unwashed	90	257

There were no marked differences for N, P, K, Ca, Mg, and Mn (see Table III).

* In 1 the treatments were carried out on independent samples, while in 2, 3, and 4 each leaf was divided down the midrib and one half was cleaned and the other half left uncleaned.

TABLE III.

ELEMENTS OTHER THAN IRON.

EFFECT OF WASHING ON ANALYSIS OF LEAVES GROWN WHILE COVERED WITH BAGS OR EXPOSED (SINGLE SAMPLES).

Sample.	Date.		N		P		K		Ca		Mg		Mn	
			C.	X.	C.	X.	C.	X.	C.	X.	C.	X.	C.	X.
	1952.		per cent.		per cent.		per cent.		per cent.		per cent.		p.p.m.	
1	7th May	Washed ..	5·79	3·54	0·636	0·356	3·00	1·43	1·00 1·04	0·81	0·24	0·14	48	31
		Unwashed..	6·14	3·66	0·582	0·380	3·00	1·42	0·78 0·77	0·84	0·30	0·15	54	34
2	21st May	Washed ..	3·15	2·69	0·372	0·322	2·00	1·53	0·44	0·85	0·27	0·25	69	75
		Unwashed..	2·92	2·45	0·370	0·318	1·91	1·69	0·45	0·86	0·25	0·25	66	76
3	30th May	Washed ..	3·25	2·78	0·344	0·300	2·46	1·50	0·56	0·81	0·28	0·26	109	116
		Unwashed..	3·23	2·71	0·340	0·300	2·44	1·50	0·55	0·82	0·28	0·23	116	118
4	30th May	Washed ..	2·82	3·14	0·260	0·250	1·88	1·71	0·79	0·92	0·18	0·17	26	30·5
		Unwashed..	2·80	3·17	0·260	0·244	1·67	1·66	0·79	0·97	0·19	0·18	30	36

In 1 the treatments were carried out on independent samples, while in 2, 3, and 4 each leaf was divided down the midrib and one half was cleaned and the other half left uncleaned. C=covered. X=exposed.

The results show that the difference in iron content between washed and unwashed leaves was small when the leaves were protected from dust whereas the difference was large if the leaves were unprotected, even when grown in a greenhouse (Table II). For elements other than iron the differences between washed and unwashed leaves were small (Table III). Sample 4 was obtained from shoots which had been covered with fine mesh nylon parachute fabric ; the greater difference for iron between washed and unwashed protected leaves is assumed to be due to fine dust penetrating the fabric.

It is thus clear, firstly, that the effect of the scrubbing treatments in diminishing the iron content of unprotected leaves may be accounted for by the removal of a very small amount of dust of the type settling on objects in the vicinity and, secondly, that when the leaves are fully protected from dust, cleaned and uncleaned leaves do not give significantly different analytical figures.

Although the foregoing results lend no support to the idea that leaching of nutrients from plant cells may occur during a short immersion in water or a cleansing solution, it was considered desirable to test this possibility by direct experiment.

Leaching of elements from apple leaves.

Figure 1 shows the effect of varying the length of soaking in 0·3 *N* hydrochloric acid on the values for potassium and iron in replicate samples of twelve similar apple leaves.

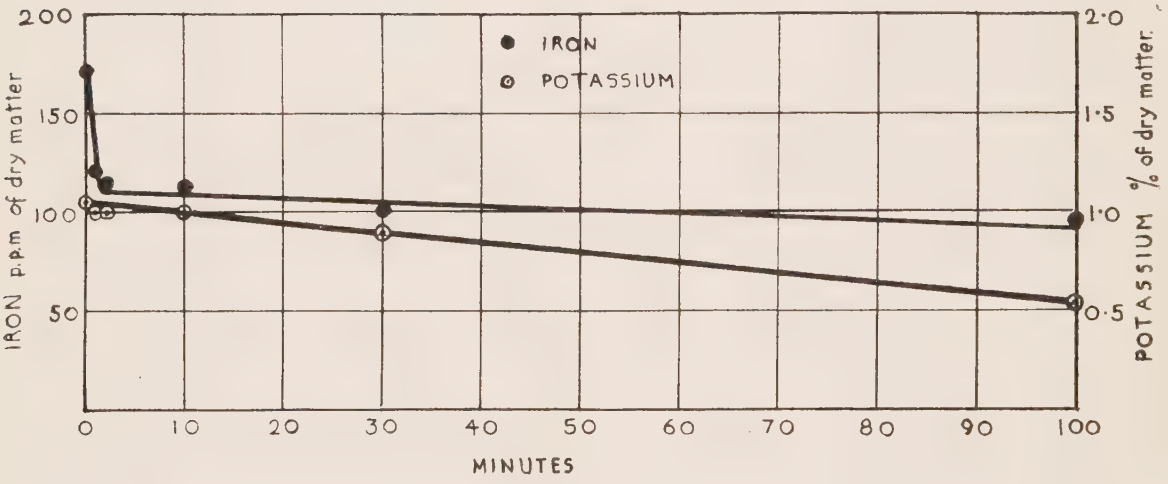

Fig. 1.

Iron and potassium content of leaves after leaching with 0·3*N* hydrochloric acid.

The amounts of both elements in the leaves decreased linearly with time, the rate of removal of potassium being greater than for iron. The initial fall in iron content, from the uncleaned leaves to the first scrubbed sample, represents the removal of surface contamination.

Analyses were also made of the wash liquors obtained after soaking cleaned leaves in 0·3 *N* hydrochloric acid or in 0·2 per cent ' Teepol ' for various periods. After 50 minutes immersion considerable leaching of potassium, but much smaller losses of iron or phosphorus, occurred. However, when immersion was reduced to one minute or less, leaching of all elements became negligible.

Recommended method of cleaning.

Hold each leaf by the petiole and, while immersed in 0·2 per cent ' Teepol ' for 10 seconds, gently scrub with a ' soft ' grade nylon tooth brush. (Although ' Teepol ', a sodium higher alkyl sulphate, has been used, there is no reason to believe that other detergents are not equally effective. 0·3 *N* hydrochloric acid is a satisfactory alternative.) Rinse the leaf in three changes of distilled water and, after shaking off the excess, lay on a piece of muslin to air-dry for a few minutes. Then, after removing the petiole and midrib from each leaf, wrap the sample in muslin and oven-dry. The washing operation, which should be rapid, can be performed at the rate of about two leaves per minute.

Because leaching is more rapid from dead than from living leaves, samples should be cleaned as soon as possible after collection.

Discussion.

The results of this work clearly demonstrate that, of the elements N, P, K, Ca, Mg, Fe, and Mn commonly determined in plant material, iron was the only one seriously affected by atmospheric dust contamination.

Although the effect of spray residues has not been examined specifically in this work, it was evident that lime-sulphur sprays, used some months earlier in the season, did not affect the calcium content, even of unwashed leaves. But, apart from direct contamination by the element under investigation, it should not be forgotten that elements such as lead and arsenic, derived from spray residues, are not readily removed from leaves except by washing (Lindner, 1943) ; and these may cause interference in the analytical methods for other elements, e.g. the unsuspected presence of lead may cause gross errors in the estimation of zinc.

Acknowledgements.

The author is indebted to Miss B. M. Kidwell, Mrs. R. D. Souter, Mr. E. C. Wills and Mrs. K. Burton for technical assistance and to the Statistics Section, who carried out the statistical analyses.

Summary.

Fine atmospheric dust, which contains a considerable proportion of iron, may settle on exposed plant material and cause serious errors in analytical results. Wiping with dry or damp muslin did not remove all surface contamination and gentle scrubbing in detergent solution or dilute acid is recommended. For elements other than iron (N, P, K, Ca, Mg, Mn) the differences between figures for cleaned and uncleaned leaves were insignificant. Leaching of nutrients from living leaves was negligible for immersion periods of a minute or less but became more serious as the immersion time was increased.

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NOTE ON THE DETERMINATION OF NITRATE IN CULTURE SOLUTIONS

By A. C. MASON

For the determination of milligram quantities of nitrate ion it is usual to reduce the nitrate to ammonia, distil, and titrate with standard acid. The classical method of reduction, due to Devarda, is too long for routine work and in our hands has not yielded consistent results. Recently, ferrous hydroxide has been employed as reducing agent in the presence of silver or copper ions. The method of Szabó and Bartha (1951), in which the silver catalysed reduction is carried out in an open flask and the excess of ferrous iron titrated with standard permanganate, is not recommended as it has given inconsistent results and is difficult to manage on account of bumping. The method to be described is based on the general recommendations of Karsten and Grabé (1948).

Procedure.

Take a quantity of nutrient solution, containing between 5 and 25 mg. of nitrate (NO_3), in a beaker and evaporate to about 10 ml. Dissolve 1·0 g. of crystalline ferrous sulphate in the solution and transfer to a semi-micro ammonia distillation apparatus. Rinse out the beaker with 5 ml. of saturated silver sulphate solution and transfer to the apparatus. Run in 15 ml. of 50 per cent w/v sodium hydroxide and distil with steam into 4 per cent w/v boric acid solution for 5 minutes as in the semi-micro Kjeldahl method. The ammonia, held in the boric acid solution, is titrated with *N*/70 hydrochloric acid using bromo-cresol green as indicator (10 ml. of 0·1 per cent alcoholic solution in 1 litre of boric acid solution). A blank is run on the reagents, under the same conditions, and its titre subtracted from that of the sample.

1 ml. *N*/70 acid≡0·886 mg. NO_3, or 0·200 mg. N.

Precision.

Results with standard nitrate solutions have been consistent.

Taken : 10 mg. NO_3 in 10 ml. of solution.

Found : 9·96, 9·96, 10·00, 9·96 (on 4th November, 1952), 9·85 (on 17th November, 1952), and 9·96 (on 12th December, 1952).

Summary.

A rapid and precise method is described for estimating milligram quantities of nitrate ion by means of a silver catalysed reduction with ferrous hydroxide and concurrent steam distillation of the resulting ammonia. The average time per determination is five minutes when several are carried out serially.

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CHLOROSIS IN APPLE LEAVES

By A. E. BRADFIELD and A. E. FLOOD

It is well known that, in leaves, yellow carotenoid pigments are closely associated with the chlorophyll, and it is clearly of interest to examine the direction and extent of variation of carotenoid pigments with variation in chlorophyll content, particularly when the latter is abnormally low. Low chlorophyll, visually evident as chlorosis, may arise from a variety of causes, but consideration here is limited to chlorosis arising from nutritional deficiencies, especially iron deficiency, or from virus infection. Some attention has already been given to the effect of iron deficiency on the pigments. Oserkowsky (1932) investigated the pigments in the leaves of Hardy pear trees suffering from lime-induced chlorosis, collecting his samples throughout a season from different positions on the tree (spurs, basal, and terminal ends of shoots), and including leaves which had become green in response to treatment with iron salts. His results demonstrated a roughly linear relationship between chlorophyll and carotenoid contents.

Again, working with barley seedlings grown in culture solutions containing or lacking iron, Mackinney (1935) found the chlorophyll : carotene ratio to be ' remarkably constant '. ' One infers ', he states, ' a straight line relationship of the type $y=mx$ between the two pigments in barley seedlings, whether they are developing normally or becoming chlorotic '. In another series of experiments, in which the seedlings were grown in media containing no iron but with potassium at high and low levels respectively, and subsequently transferred to dilute calcium sulphate solution, it was found that the level of potassium supplied had little, if any, effect on the development of chlorosis or on the chlorophyll : carotene ratio, though it did affect the recovery of the plants, as shown by pigment formation in the plants subsequently given iron. In this series of experiments the chlorophyll : carotene ratio was less constant and the mean value somewhat higher than in the first series.

Chlorophyll: carotene ratio in apple leaves.

A preliminary investigation has now been made of the chlorophyll and carotene contents of both healthy and chlorotic leaves of an apple rootstock (M. VII).

As samples, single leaves, or where the leaves were small, pairs of leaves, were collected during August and September, 1951. These included chlorotic leaves from plants grown in an iron deficient medium by a spray culture method, chlorotic and green leaves from plants grown similarly in a potassium deficient medium, and chlorotic and green leaves from field grown plants which had been infected with severe mosaic virus disease. The leaves were taken from different positions on the shoot, and in every case a similarly placed leaf was taken for comparison from a plant supplied with full nutrient solution, in the case of the spray culture samples, and from a neighbouring plot, in the case of the virus infected plants. Analysis of the samples was carried out by the methods described below. The results for all the samples are shown in Fig. 1, in which chlorophyll content is plotted against carotene content. A regression analysis showed that the data could be represented by the regression line $y=17\cdot9x+0\cdot08$, y and x being the amounts of chlorophyll and carotene, respectively, in milligrams per gram fresh weight. This regression line is drawn in the figure, together with ' 95 per cent confidence ' curves on either side. The experimental values for y vary between $0\cdot35$ and $3\cdot49$ with a standard error of $0\cdot16$ for a mean value of x. The tentative conclusion that the carotene content is a linear function of the chlorophyll content in both healthy and chlorotic leaves, whether chlorosis is due to mineral deficiency or to disease, is somewhat unexpected. Several hypotheses could be formulated to explain this interdependence of the pigment concentrations, but it would be premature to discuss them with the limited data available. It should be noted that total carotenoids were not determined.

Experimental methods.

Extraction.

The pigments were extracted from the fresh leaves and separated by methods based on the recommendations of the Analytical Methods Committee of the Society of Public Analysts (1950). As the acetone-petrol ether solvent recommended by the Committee for the extraction of fresh grass was

found to be unsuitable for apple leaves, chlorophyll was determined colorimetrically on the extract prepared by grinding the leaves with 95 per cent acetone and quartz. The pigments were then transferred to petrol ether solution and the carotene separated on a bone-meal column and determined colorimetrically as below.

Colorimetric measurements.

These were made on a Spekker Photoelectric Absorptiometer, using Ilford filters Nos. 601 and 608 for carotene and chlorophyll respectively.

A calibration curve in terms of arbitrary units was obtained by serial dilution of a chlorophyll solution. With the No. 608 filter this curve departs widely from linearity. A more nearly linear curve is obtained with No. 607 filter, but the wave-band passed by the filter corresponds to a subsidiary peak of the chlorophyll absorption spectrum. The measurements now reported were all made originally in terms of arbitrary units as described. Subsequently, a Unicam Spectrophotometer became available, with which it was possible to determine the chlorophyll concentration of a solution in absolute units, using the data of Mackinney (1941). With a standardized chlorophyll solution prepared from leaves of the same rootstock employed in the earlier experiments, the Spekker readings were then converted to absolute units (mg. total chlorophyll per g. fresh weight). These values were used for Figure 1.

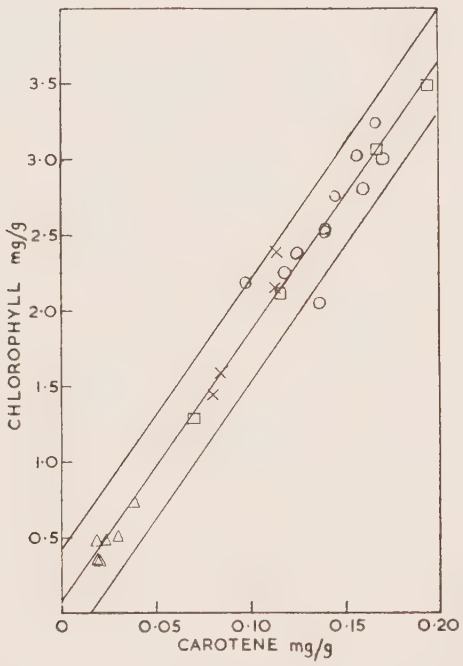

FIG. 1.

Chlorophyll and carotene in leaves of Malling VII apple rootstock.

○ Healthy leaves. × Potassium deficient leaves.
△ Iron deficient leaves. □ Virus infected leaves.

The Spekker readings for carotene were converted to absolute units by means of a standard solution of β-carotene, prepared from a commercial specimen of β-carotene. Subsequently, using the Unicam instrument, this specimen was found to have $E^{1\%}_{1cm.}$ =2400 at λ=449. Glover, Goodwin, and Morton (1948) quote $E^{1\%}_{1cm.}$ =2500 at λ=450 for β-carotene as the accepted value.

Acknowledgements.

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Summary.

Using Malling VII rootstock, chlorophyll and carotene have been determined in healthy leaves and in leaves exhibiting chlorosis arising from (*a*) iron deficiency, (*b*) potassium deficiency, and (*c*) virus infection. A linear relationship is found between the amounts of the pigments.

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PLANT PATHOLOGY

VERTICILLIUM WILT OF THE HOP

VII. FURTHER STUDIES ON WILT-RESISTANT VARIETIES

By W. G. KEYWORTH, MARGARET M. HITCHCOCK, and PAMELA M. GOODE

Earlier work on the resistance of hops to the progressive type of wilt caused by *Verticillium albo-atrum* (virulent race) has already been reported (Keyworth, 1942, 1947a, 1947b). It was shown that none of the commercial varieties had high resistance, but that several Wye seedling varieties, bred by Professor E. S. Salmon, were highly resistant. The test methods involved primary selection trials in which the untested varieties were grown in randomized plots in artificially infested soil. Varieties selected from these primary trials were then grown in naturally infested soil in commercial gardens where their field performance could be judged and a crop of hops collected for brewing tests. These second-stage farm trials were on a fairly small scale, usually containing about 50 plants of each variety and including control Fuggle plants, arranged in randomized plots.

As a result of these trials, two varieties, OR55 and OJ47,* were selected as of most commercial promise (Keyworth, 1947b). Improved methods of propagation by layering were devised (Keyworth, Hitchcock, and Wilson, 1948 ; Keyworth and Wilson, 1948) and these methods were used by the Hops Marketing Board to raise large numbers of sets of the varieties OR55 and OJ47. These were distributed to hop growers from 1949 onwards and more extensive observations made on their performance under normal commercial conditions. These observations are reported here.

At the same time, more primary selection trials were made each year with previously untested Wye varieties. Breeding of daughter seedlings from known resistant varieties was also started, and these new seedlings were tested and propagated. All this work is described below.

Primary selection trials 1947-51.

The methods used in these trials were slightly modified from those previously in use (Keyworth, 1947a). In order to conserve inoculum and also to conform with methods used in other tests, the naturally infected hop stem used to infest the soil was not scattered in trenches. Instead, about 10 g. were placed in each planting hole immediately beneath the roots of each ' set '. The trials usually contained 30 plants of each variety randomized in three plots (or 20 plants in four randomized plots if planting material was in short supply). Up to 1947 the trials were all made on a plot of heavy loam near Paddock Wood, Kent. This was necessary since symptoms were usually too mild on plants grown on the experimental plot at the Research Station. Other studies showed, however, that this was due to insufficient nitrogenous manuring of the latter piece of ground (Keyworth and Hewitt, 1948). When sulphate of ammonia, at a rate of 2-3 oz. per yard of row, was applied shortly after planting, severe symptoms could be induced on the control plants. The experiments were, therefore, gradually transferred to the Research Station.

The accumulated results of the trials are given in Table I.

Of the varieties showing high resistance one, OT48 (Bramling Cross), was regarded by Salmon (1951) as having good growing and brewing qualities, and it was therefore propagated for further tests on farms. None of the other varieties appeared to be superior to the 1942-1946 selections (OR55, OJ47, etc.), so no further tests were made with them. Stock plants of some have been reserved for further propagation if necessary.

Assessment of relative resistance by means of primary selection trials.

In the assessment of Wilt-resistance, the purpose of the primary selection trials has been to provide a first ' screen ' whereby varieties with low resistance could be eliminated. When the trials were first devised it was hoped, however, that the more promising varieties could be accurately graded in terms of relative resistance. Experience has now shown that this is not possible.

* Subsequently named ' Keyworth's Midseason ' and ' Keyworth's Early ' by Salmon (1949).

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TABLE I.

ACCUMULATED RESULTS OF 1947-51 PRIMARY SELECTION TRIALS OF WYE SEEDLING VARIETIES.*

Percentage Wilt.	Female varieties.	Male varieties.
0–10	OE48.	211, 321.
11–20	AOY17, OT48.	OB79, OL45, OR80.
21–30	OH20, R17, WFA69, X92a.	A10a, II55, R3/43.
31–40		II53, II121, 316 (Wild Italian).
41–50	OC5, OH96, WFB91.	II10.
51–60	AOW2, ON65, OR137.	OM52, OS83, OW81.
61–70	CC53, ON78.	OB102, OT59, WF15.
71–80	AA111, AOR30, CC6, OF8, OO82, WFD88, 17/49 (=*H. lupulus* var. *Cordifolius* (Wild Japanese)).	II54, M24, WFH20.
81–90	D19a, GG69, OO81, 168a (*H. lupulus* var. *Neomexicanus*), OB26 (Wild Italian).	II40.
91–100	AA102, AOO34, B1a, CC66, EE79, II129, OA66, OF106, OG9, OQ99, OR47, OS64, OX60, WFC81, Z13, 368.	BB85, EE19, II31, II91, II127, W57.

* *Note.*—The following varieties were rejected on the results of small-scale tests : AA84, A19a, A53/26♂, AOM12, AOV32, B69/13♂, BB26, BB47, BB023, DD57, EE55, F12/15♂, FF40, FF54, GG19, HH58, M21, OA61, OD107, OJ26, OJ36, OJ22, OM97, ON44, OQ98, OR33, OT9, OV119, OV124, OW16, OX23, OX40, R1/2, R1/5, R1/11a, R1/29a, R1/64, R2/63, R3/1a, R4/94a, R13, S14, WFA136, WFB21, WFD33, WFD100, WFE25, WFF37, WFF118, WFF121, WFF142, X3, X93, X95, Z84, 42a, 143, 337

there was a considerable variation in the performance of these varieties from year to year. Varieties selected in previous trials were sometimes included in the primary trials as high-resistance controls. Wilt incidence in these varieties during the years 1943-51 is given in Table II.

TABLE II.

WILT INCIDENCE IN SIX RESISTANT VARIETIES IN PRIMARY SELECTION TRIALS, 1943-51.

Percentage Wilt.	1943.	1944.	1945.	1946.	1947.	1948.	1949.	1950.	1951.
0-10	OB53 OR55 1147			OR55		OM26	OB53 1147	OB53	OB53 1147
11-20				OM26 1147	OT48				OR55
21-30		OJ47						OT48	
31-40									
41-50								OR55	OJ47

It will be noted that in every year in which it was tested, the variety OB53 showed less than 10 per cent Wilt. This is in agreement with the results from farm trials in which the variety has generally shown very little Wilt. On the other hand, the varieties OR55 and OJ47 varied in Wilt incidence in the primary trials between 0 to 10 per cent and 41 to 50 per cent. The variety 1147 showed less than 20 per cent Wilt on all four occasions on which it was tested. In field trials, however, it appears to have no greater resistance than OR55. The Fuggle variety, which may be taken as representative of those varieties having very low resistance, has always shown 91-100 per cent Wilt in the primary trials.

The causes of the year to year variations in the relative performance of the resistant varieties are unknown. It should be pointed out that the trials were not conducted with pure cultures of the pathogen, since the soil was infested by adding naturally infected hop bine. Nor was it always possible to obtain the bine from the same farm every year. It is, however, thought unlikely that the results can be explained on the grounds of differing fungal pathogenicity (see also below).

Whatever the causes of this variation, it is apparent that the primary trials do not enable the relative resistance of the varieties to be defined precisely. The broad classification adopted in previous publications (Keyworth, 1947b) is probably still the best that can be devised.

Farm trials.

Before 1947 it was customary to plant selected varieties in randomized small-scale field trials on farms. The results of several of these trials have already been reported. These tests were regarded as of an interim nature, until sufficient sets could be obtained for larger-scale planting. The development of layering methods, however, enabled planting material to be grown more quickly from 1947 onward, and testing methods were consequently changed. The interim trials were discontinued and larger ' block trials ' of selected varieties (without any control plots) were planted on farms. This procedure, although giving a less exact comparison of varieties, was found more acceptable to growers since the hops could be picked in bulk. It also made the trials more manageable and enabled several years' successive records to be taken.

Notes on the results obtained with several varieties are given below :

FF21 (*Early Choice*). This variety had been selected in 1945 when it showed 26 per cent Wilt in the primary trial. In 1947, 586 sets were planted in a field in which another variety had shown 70 per cent Wilt in 1946. Only 7 per cent of the FF21 plants wilted in 1947, but in 1948, 42 per cent were affected, 33 per cent severely. The variety was thus considered unsuitable for further trials.

OR55 (*Keyworth's Midseason*). As this variety was regarded as the most promising of the selected Wye seedlings it was intensively propagated in the years 1946-49. Many farm trials were thus possible.

In 1948 the variety was grown on seven farms in plots varying in size from 90 to 1,572 plants. Severe Wilt had previously occurred (in Fuggles) on all sites, but on two of them no hops had been grown in 1947. Wilt incidence on the plots varied from 1 to 33 per cent (an average of 18 per cent), being least on those sites ' fallowed ' for one year. Owing to the high Wilt incidence many of the smaller plots were grubbed in 1949. On the larger plots which were retained, the severely wilted plants were replaced and recording was continued. The records showed that, contrary to experience with the Fuggle variety, the replants usually survived and most of the originally wilted plants recovered completely in subsequent years. Details of two such cases are given below.

Site A. 1,572 plants planted in 1948, where there had previously been 75 per cent Wilt in Fuggles. No ' fallow ' period.

In 1948 there was 24 per cent Wilt ; in 1949, 5 per cent ; in 1950, 0·6 per cent ; in 1951, no Wilt.

Site B. 668 plants planted in 1948, where previously 27 per cent Wilt in Fuggles. One year ' fallow ' period.

1948 9 plants wilted.

1949 7 of the 9 that had wilted in 1948 recovered ; 2 again wilted. 13 other plants wilted. (Total with Wilt, 15.)

1950 12 of the 15 that had wilted in 1949 recovered ; 3 again wilted. 5 other plants wilted. (Total with Wilt, 8.)

1951 7 of the 8 that had wilted in 1950 recovered ; 1 showed mild Wilt. 1 other plant wilted. (Total with Wilt, 2.)

On site A there was a progressive reduction in the amount of Wilt recorded. On site B, where Wilt was not severe, the numbers of affected plants fluctuated from year to year. This is a characteristic of fluctuating Wilt (caused by the mild race of *V. albo-atrum*) in the Fuggle variety. It has been apparent in other plots of highly resistant varieties. In addition, many of the affected OR55 plants developed swollen bines and showed sectorial yellowing and necrosis of the leaves. These are also characteristic of fluctuating Wilt in Fuggles. There thus appears to be a close similarity between the effects of the mild race of *V. albo-atrum* on the Fuggle variety and the effects of the virulent race on the variety OR55 (and other varieties of similar resistance).

In 1949 between 1,000 and 2,000 plants of OR55 were distributed to each of 15 farms by the Hops Marketing Board for replanting gardens in which Wilt had occurred. On 13 of these farms a period of at least one year had elapsed since hops had been grown on the site used for planting. In some cases no hops had been grown for four years or more. No Wilt was recorded on 7 of the 13 sites. On the other 6, Wilt incidence varied from 0·1 to 1·5 per cent but decreased greatly in 1950 and 1951. On all 13 farms, therefore, the variety was readily established.

On 2 farms where there was no fallow period the disease was somewhat more severe, amounting to 5 per cent and 10 per cent respectively in the first year. As in the other cases, however, disease incidence became less in subsequent seasons.

It is now clear that this variety is quite sufficiently resistant to Wilt to be planted in gardens in which the Fuggle variety has shown severe symptoms. In order to ensure a good stand of plants in the first season, however, it is advisable to grow a non-susceptible crop on the ground for at least one year before the OR55 is planted.

OJ47 (*Keyworth's Early*). This variety has not had so many farm tests as OR55, mainly because of the shortage of planting stock resulting from its poor propagating qualities. It has not proved entirely acceptable to growers because it is rather subject to Mould and to Downy Mildew.

It was planted in plots of from 150 to 1,000 plants on three farms in 1948 and 1949 and also more extensively on one large farm. Wilt incidence was very similar to that in the variety OR55. For the reasons already given, and because it is not acceptable to many brewers, the variety is not now being widely planted.

1147. This variety was one of many bred on a commercial farm some 40 years ago. Its female parent is thought to have been the old variety Bates Brewer but its male parent is unknown, though probably of British origin. It was discovered to have high resistance because a planting of it remained healthy in a garden in which other varieties contracted Wilt severely. The variety has since been used extensively on this farm for reclaiming affected ground, but it has not been tested elsewhere. Comparisons with the varieties OR55 and OJ47, grown on the same farm, in respect of Wilt incidence in 1949 and 1950, are given in Table III.

TABLE III.

WILT INCIDENCE IN VARIETIES 1147, OR55, AND OJ47 ON ONE FARM IN 1949 AND 1950.

Variety.	Number of plants.	Per cent Wilt.	
		1949.	1950.
1147	41,360	0·6	1·0
OR55	11,630	1·6	0·39
OJ47	11,020	0·37	0·24

From these records and from the primary trials already described, it is apparent that the resistance of 1147 is of a similar order to that of OR55 and OJ47. The variety gives a moderate crop and seems acceptable at present to those brewers who have tested it. It may, therefore, prove of value to other growers when available for general distribution, but it has proved difficult to propagate.

AEE55, OB53, OM26, 219. These varieties, mentioned in the previous reports (Keyworth, 1947a and 1947b), were given further tests on farms, but were eventually rejected because of poor growing qualities.

Goldings and Golding varieties. Several Golding hops (notably Bramling), and also the Golding varieties Tutsham and Cobb, have occasionally been used by growers for reclaiming affected gardens after a considerable 'fallow' period. They have sometimes proved satisfactory for this purpose, although not entirely suited to very heavy soil. The varieties may have a rather higher resistance than Fuggle when not exposed to very heavy infection. The comparison of their resistance with that of OR55 made in the 1948 primary selection trials showed, however, that they could not survive in heavily infested soil, in which OR55 showed little Wilt.

OT48 (*Bramling Cross*). As already mentioned, this variety was the only Wye seedling selected for farm trial during 1947-51. The results of these trials are not complete, but the variety would seem to be at least as resistant as OR55. It has also received favourable reports from some brewers and may be of value to growers. Its cultural characters have been recently described by Salmon (1951).

Pathogenicity tests of isolates of *V. albo-atrum* from three farms.

In field trials made during 1944-46, several varieties showed considerable variation in Wilt incidence on different farms. This is illustrated by the performance of the three varieties Fuggle, OB53, and 219 on three farms.

Farm A. Disease annually severe in Fuggle variety. In 1946 trial OB53 and 219 wilted only slightly (2 per cent and 5 per cent respectively).

Farm B. Disease less severe in Fuggle variety than on Farm A, but in 1946 trial OB53 showed more severe Wilt (9 per cent) than on Farm A.

Farm C. Wilt in Fuggle variety similar to that on Farm B. In a trial in 1945, OB53 showed no Wilt, but 219 was much more severely wilted (21 per cent) than on Farm A.

Cultures of *V. albo-atrum* were made from a Fuggle plant on Farm A, from an OB53 plant on Farm B, and from a 219 plant on Farm C. These were grown on autoclaved hop stem and, after two months' growth, used for soil inoculation. 12 g. of inoculum was placed in contact with the roots of each set at planting, 22nd May. The experiment was made on two sites, at East Malling (1) and near Paddock Wood (2). On each site, 32 plants of each of the varieties Fuggle, OB53, and 219 were exposed to inoculum of each fungal strain, in four randomized plots of eight plants each.

Summaries of the final Wilt records are given in Table IV.

TABLE IV.

SUMMARY OF WILT RECORDS IN PATHOGENICITY TRIAL.

Variety.	Source of pathogen.	Site 1.			Site 2.		
		No. of plants.*	Severe Wilt, %	Mild Wilt, %	No. of plants.	Severe Wilt, %	Mild Wilt, %
OB53	A	22	31	5	29	0	3
	B	21	5	0	30	0	0
	C	26	12	8	32	0	0
219	A	30	20	0	32	3	9
	B	31	17	20	31	0	0
	C	31	17	6	32	0	0
Fuggle	A	32	100	0	32	69	28
	B	32	97	0	32	63	31
	C	31	100	0	32	66	31

* *Note.*—There was a rather high initial mortality in the variety OB53 on Site 1, probably owing to the late planting date.

These results indicate that the three isolates of *V. albo-atrum* were similar in their pathogenicity toward the test varieties. On Site 1, strain A affected the variety OB53 slightly more severely than strains B and C, but this result was not significant. There was, on the other hand, very much more Wilt in all varieties on Site 1 than on Site 2 ; the cause is unknown.

The comparison of three single isolates in this way cannot, of course, be regarded as a comparison of the Wilt potentialities of the strains of Verticillium present on the three farms, since nothing is known of the variation between different isolates from each farm. The results may, however, be taken as an indication that the variation in the field performance of resistant varieties may be related more to local environmental conditions than to differences in fungal pathogenicity.

Breeding of new Wilt-resistant varieties.

As described previously (Keyworth, 1947a), the Wye varieties were bred by Professor Salmon for cultural characters, and not for resistance to Verticillium Wilt. For this reason it was thought advisable in 1944 to start a new breeding programme at East Malling, placing emphasis on the Wilt reaction of the new seedlings produced. The main object of the programme was to breed Wilt-resistant male hops. These were required, both for planting in Wilt-affected hop gardens (to pollinate the selected Wilt-resistant female varieties) and for further breeding work. In the course of this programme, new Wilt-resistant female hops were also produced and these were propagated for further test.

In 1944 no Wilt-resistant male hops were available for breeding work and little was known of the cultural characters likely to be transmitted by any male hop. The only possible advantage, therefore, in breeding from selected male plants would have been the ability to repeat the cross. This was considered to be outweighed, however, by the fact that restriction of the male parentage might have resulted in a preponderance of undesirable cultural characters. For these reasons, the first group of seedlings (1944) were grown from seed collected in the field from the unbagged cones of Wilt-resistant female varieties. These had been wind-pollinated by unknown, and possibly diverse, male plants.

In 1945, a male plant apparently possessing slight resistance to Wilt was used for some of the crosses.

The last crosses were made in 1946 when the resistant variety 1147 was pollinated by another

male plant possessing some Wilt resistance. At the same time, ' open-pollinated ' seeds were also collected from other 1147 plants.

The seeds obtained each year were sown in flats of soil in the greenhouse and the young plants pricked into ' small 60 ' pots in March-April. They were usually large enough for field planting in June and were grown on to form a small set at the end of the season. These sets were then used in the following year for a single-plant resistance test. This test was made in the same way as the primary trials already described. It constituted the first screening of the new seedlings and was intended only to eliminate those of low resistance.

The plants selected by the test were given a code letter to denote their parentage. A list of these code letters, together with the number of seedlings in each group, is given in Table V.

TABLE V.

PARENTAGE AND NUMBERS OF SEEDLINGS BRED IN 1944-46 AND SELECTED FROM SINGLE-PLANT RESISTANCE TESTS.

Year.	Code letter.	Parentage.	Number.
1944	A	AEE55 Open crosses.	12
	B	AOO10 ,, ,,	13
	C	OB53 ,, ,,	7
	D	OR55 ,, ,,	16
1945	E	AEE55 × resistant male.	31
	F	OR55 × ,, ,,	7
	G	OJ47 × ,, ,,	2
1946	J	1147 Open crosses.	7
	L	1147 × Male No. 15 (resistant).	5

In the case of the 1944 and 1945 seedlings (A-G) the sets used in the single-plant test were the only available plants of each seedling. They thus had to be used for further propagation although they were really unsuitable because, although not killed by *Verticillium*, they almost certainly contained the fungus. For this reason a very close watch was kept for any sign of the disease in the cuttings and sets produced in subsequent years from this material. None was seen, however, and, after several years' growth in non-contaminated soil, the stock of sets was regarded as disease-free.

This difficulty did not arise with the J and L seedlings since they were propagated to give at least two plants of each before the single-plant test. Besides the plant used in this test, there was thus another one of each seedling which could be used for propagation.

The next stage in the testing of the new seedlings was a 30-plant randomized trial similar to the primary selection trials of the Wye seedlings. During the 2 to 4 years between the single-plant and 30-plant test, several hills of each variety were grown and observed for cultural characters. On these characters, and on the results from the 30-plant tests, further selections were made. Any female seedlings of promise were planted in larger trials on farms.

To date, three varieties have reached the farm trial stage. These are C2, D1, and D3. Brewing tests of these varieties are not complete, however, and must be awaited before their commercial suitability can be assessed. Meanwhile, the variety J2 and possibly other J seedlings appear of some promise.

Several of the new male seedlings have proved to be highly resistant to Wilt. They have already been used in further breeding work designed to produce seedlings which combine resistance to Wilt with the desirable commercial qualities of the Fuggle and other varieties.

Discussion.

The studies on hop Wilt since 1938 have indicated only two possible control measures. One of these is to abandon hop growing on affected fields or whole farms for many years (probably at least seven), after which an attempt can be made to grow the Fuggle or similar commercial varieties again. The other control measure is to replant the affected gardens with a Wilt-resistant variety, preferably after the lapse of one or two years.

In the belief that this second measure was the more practical of the two, much of the research since 1942 has been concerned with the development of varieties suitable for such replanting.

Reliance on host resistance for the control of a disease involves the danger of a possible breakdown of this resistance due to the development of new strains of the pathogen. This possibility does not

constitute a valid reason why resistant varieties should not be used. It does necessitate, however, a careful watch for signs of any breakdown of resistance together with the development of a reserve of varieties of varied genetic constitution, which might contain the factors for resistance to new strains of the pathogen.

However, in the ten years during which Wilt-resistant hop varieties have been studied, no indication has been seen of any breakdown. Severe Wilt in these varieties seems to be induced by environmental factors, and not by increased fungal pathogenicity. In addition, in every case where several years' records have been taken in farm trials, there has been either a progressive reduction or a fluctuation in disease incidence from year to year.

In the selection of varieties, three criteria have been considered, viz. —(*a*) Wilt resistance, (*b*) cultural suitability, and (*c*) brewing value. The method of test, and the improved means of obtaining planting stocks, now enable Wilt resistance to be assessed fairly readily. The other criteria are much more difficult to assess, however ; this difficulty constitutes the main obstacle to the rapid development of resistant varieties suitable for replacing the Fuggle hop on affected farms.

Many of the varieties selected to date have been Wye seedlings and much cultural information on them has been available from the records of trials at Wye and East Malling. This has been supplemented by observations on the resistance trials on farms. Even so, the assessment of the cultural suitability of the selected varieties is still not complete although one, OR55, seems fairly generally acceptable to growers.

Advice on the brewing value of the varieties has been given by numerous breweries and through the Hops Marketing Board. The assessment of this factor is still not complete for any variety, however, widely different views having been advanced by different authorities.

It would thus appear that, although many Wilt-resistant varieties have been found, none is yet regarded as an entirely acceptable substitute for the Fuggle hop. The only hope of obtaining such a variety, or range of varieties, would seem to be to breed specifically for the required characters. As described, a start was made on such breeding work in 1944 and this had yielded Wilt-resistant male hops which can be used for further breeding projects.

In collaboration with Wye College, one such project was started in 1950 in an attempt to combine Wilt-resistance with desirable cultural and brewing qualities. Some 2,000 new seedlings were produced and they received a single-plant resistance trial in 1952. The selections from this trial are now being propagated for further tests. There seems little doubt that this or future projects will eventually produce a suitable range of resistant hops. This may, however, take many years and, during that time, the varieties already selected must continue to be used by growers who wish to plant up affected gardens.

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Summary.

An account is given of further studies on Wilt-resistant varieties since 1947. The results of primary selection tests and large-scale field trials are described. It was found that the more resistant varieties varied in relative Wilt incidence both from year to year and from farm to farm. The causes of these variations were probably environmental and not related to differences in pathogenicity between fungal strains.

In field trials most of the selected varieties showed progressively less Wilt in succeeding years. The types of symptoms were also similar to those typical of fluctuating Wilt in the Fuggle variety.

Breeding of resistant varieties was started in 1944 and has yielded resistant male hops for further breeding work, as well as several female varieties of promise. It is concluded that none of the varieties selected to date provides an entirely satisfactory substitute for the Fuggle variety. The development of such varieties can best be accomplished by further breeding studies such as have already been started.

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INSECT VECTOR STUDIES WITH MOSAIC AND OTHER VIRUS DISEASES OF THE HOP

By J. PAINE

Although Salmon described Mosaic disease of the hop in 1923 and Thrupp demonstrated that it was graft transmissible in 1927, the way in which it spreads in the field was unknown when this investigation was started in 1948. Evidence that the Hop-Damson Aphid, *Phorodon humuli* (Schr.), and the Potato Aphid, *Macrosiphum euphorbiae* (Thos.) are vectors is given in the following account which is limited to those experiments yielding positive results among the 40 carried out with hop viruses and insects at East Malling in the seasons 1948 to 1951. The experiments are described here in logical, not chronological, sequence.

Time of spread.

Ten healthy plants of Petham Golding, a variety sensitive to the mosaic virus (Keyworth, 1947), were exposed each month in hop gardens of Mosaic-carrier varieties at East Malling. Each group of potted plants, trained on bamboos, was placed in the hop garden for a month, with regular watering, and then returned to the glasshouse where the plants were stored under insect-proof conditions. Symptoms of Mosaic developed on three plants, two of which had been exposed in June and the other in July.

Insects found on hops between May and July.

During 1950, records were kept of the insect species found in five hop gardens where Mosaic disease was known to spread, and in 1951 similar records were made in the hop garden at East Malling where the plants exposed in June and July became infected. A complete list of insects collected has already been published (Paine, 1952).

Thirty-five species were recorded between May and July in 1950, and 23 in 1951, but only the following occurred in the May-July period of both years :

Anthocoris nemorum (L.)	*Longitarsus parvulus* (Payk.)	*Psylliodes attenuata* (Koch)
Capsids (unclassified)	*Macrosiphum euphorbiae* (Thos.)	
Ladybirds (unclassified)	*Phorodon humuli* (Schr.)	

Mass infestation of hops.

All the insects collected throughout the 1950 growing season from the five different sites where the disease was known to be spreading, were tested for their ability to carry the virus. In previous experiments with possible vectors, the number of insects and their feeding times had been regulated, so the conditions under which transmission could take place might not have been fulfilled. Accordingly, at monthly intervals, all the insects which could be collected in one hour were placed on infected plants in the glasshouse, and later transferred to Mosaic-susceptible Bramling plants. When each of the 90 test plants had been infested once, the first plant was used again for the next batch of insects, and all the test plants were re-infested as the collections proceeded. In this way some plants received as many as six different insects during the course of the experiment. An attempt to limit the distance travelled by the alate forms by clipping their wings was only partially successful, and so care was taken to make frequent records of the insects which settled on any particular plant.

Two Bramling plants developed Mosaic symptoms in the year they were infested and two more in 1951 ; in addition, four others showed symptoms of Split Leaf Blotch* (Table I). Nine different species of insects and soil from around infected plants were used in various combinations in such a way that no two plants received the same treatment ; in fact only one species, *Phorodon humuli*, was common to all infected plants. The next experiment was therefore limited to this aphid.

* Split Leaf Blotch (Keyworth, 1951) is a virus disease commonly found in the Fuggle variety, of which there is no known clone entirely free from the disease. It was not present in the Bramling test plants and it seems probable that the split leaf blotch virus had been carried from the Fuggle to the Bramling, although some of the infector plants may not have been showing symptoms at the time of the experiment.

TABLE I.

TREATMENTS GIVEN IN 1950 TO EACH TEST PLANT WHICH BECAME INFECTED.

Test plants.	Treatment. Insect species. A	B	C	D	E	F	G	H	I	Soil. J	Symptoms.
1	x	x	x			x			x	x	Mosaic 1950
2	x			x				x			Mosaic 1950
3	x	x								x	Mosaic 1951
4	x			x							Mosaic 1951
5	x	x			x						
6	x		x		x		x				Split Leaf Blotch 1951
7	x		x								
8	x										

Key to treatments :

A=*Phorodon humuli* (Schr.), winged form. B=*Macrosiphum euphorbiae* (Thos.). C=*Tetranychus urticae* (Koch). D=*Chlorita* sp. E=Olive coloured aphid (unclassified). F=Unidentified aphid from *Veronica* sp. in infected hop garden. G=Froghopper (unclassified). H=Thrips (unclassified). I=Wireworm (unclassified). J=Soil from diseased hills in badly infected hop garden.

Virus transmission by winged Hop-Damson Aphids (*Phorodon humuli*).

In May and June, 1951, winged Hop-Damson Aphids were collected from Bullace, Damson, Myrobalan, Sloe, and Hop, and kept without cages for six weeks in an insect-proof glasshouse containing ten Mosaic-infected and ten healthy plants, which were planted in pots in pairs consisting of one Fuggle infector and one Petham Golding test plant. The aphids were transferred from their host plant in three ways : (1) they were allowed to fly direct to the hops from the host plants on which they had been brought to the glasshouse, (2) they were transferred by hand from host plant direct to the test plant and (3) they were transferred by hand from the host plant first to infected and then to test hop plants. A few of the wingless forms which had bred on the hop were also transferred.

Nine out of ten of the test plants developed a line-pattern type of symptom (Fig. 1) within a few months of infestation, and four, including the one which did not show line-pattern, developed Mosaic symptoms (Fig. 2) in 1952. The control plants, which received no insects, remained without symptoms.

Virus transmission by Potato Aphids (*Macrosiphum euphorbiae*).

Two plants which became infected with Mosaic and one with Split Leaf Blotch in the mass infestation experiment (Table I) had been infested with two species of aphid, *P. humuli* and *Macrosiphum euphorbiae* (Thos.). The latter species was re-tested in 1951 when over 1,000 wingless aphids were transferred repeatedly between ten Mosaic-infected plants and ten healthy test plants (Petham Golding) planted together as pairs in pots in the glasshouse.

Three test plants developed line-pattern symptoms three months after infestation. The ten plants were planted outside the glasshouse in 1952, and two showed Mosaic symptoms in May and July respectively. No symptoms were seen on the ten control plants.

Discussion.

The egg of the Hop-Damson Aphid hatches on *Prunus* spp. in spring and, after some wingless generations, the winged form develops and flies to the hop, where it gives birth to the wingless hop aphid. This reproduces itself asexually for the whole of the summer unless exceptional circumstances, such as overcrowding, induce a winged generation (Theobald, 1926). In September, winged females develop on the hop and fly back to the *Prunus*, there to give rise to wingless females which are fertilized by winged males arriving later from the hop. There are therefore three and possibly four different winged forms of the Hop-Damson Aphid, but only the early summer form was used in these experiments.

Because Mosaic disease can be contracted in the field in June and July, the vector is assumed to be active then, and the Hop-Damson Aphid and the Potato Aphid are among the commoner insects to be found in hop gardens at that time. In one experiment, eight test plants contracted either Mosaic or Split Leaf Blotch, and although nine different species of insects were applied to these eight plants, *Phorodon humuli* was the only one common to all ; three of them also received *Macrosiphum euphorbiae*.

When winged Hop-Damson Aphids were transferred in very large numbers to Petham Goldings from various *Prunus* species as well as from hops, nine out of ten plants showed line-pattern in the same season, and four developed typical symptoms of Mosaic in the following year. Since none of the controls showed line-pattern, it is thought that the aphids were responsible for the appearance of this symptom, which is assumed to be caused by a virus, although it has not yet been transmitted by grafting. In numerous case-histories of hop plants infected by grafting, line-pattern did not precede Mosaic symptoms. If graft-transmission proves that line-pattern is caused by a virus, further investigation will be necessary to find out whether the aphids carried it from hops in the field, or from the infected Fuggle in the glasshouse, or even from the *Prunus* from which some were collected, although the apparent transmission of line-pattern by *Macrosiphum euphorbiae*, which did not feed on *Prunus*, renders the last alternative improbable.

The possibility that the few wingless forms of the Hop-Damson Aphid which were transferred were responsible for transmission of Mosaic and the appearance of line-pattern seems remote, because no transmission occurred among the 128 susceptible hops which were infested with more than 3,500 wingless aphids in 1948. Infective and non-infective ' races ' within a species are not uncommon, and Storey (1933) demonstrated with the vector (*Cicadulina mbila*) of Maize Streak that this was due to differences in the permeability of the gut wall ; but no instance is known where one form of an aphid is able to transmit a virus while another form of the same species is not. This phenomenon with *Phorodon humuli*, and the apparent transmission of the split leaf blotch virus by two aphid species, offer interesting fields for future research.

Acknowledgements.

Acknowledgements are particularly due to the author's colleague, Mr. P. J. Ormerod, and to Mr. J. F. Wilson, then technical assistant to Messrs. Arthur Guinness, Son & Co., for their assistance throughout this research.

Summary.

The spring migrant winged form, but not the apterae, of the Hop-Damson Aphid, *Phorodon humuli*, and the wingless form of the Potato Aphid, *Macrosiphum euphorbiae*, have been shown to transmit the virus causing Mosaic in hops. Both aphid species apparently also transmitted the split leaf blotch virus and a suspected virus with line-pattern symptoms.

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Fig. 1.
Line-pattern symptoms on Petham Golding hops.

Fig. 2.
Mosaic symptoms on Petham Golding hops.

[face p. 122

THE NATURAL SPREAD OF NETTLEHEAD DISEASE OF HOPS

By J. T. LEGG

Nettlehead was first described over 50 years ago (Percival, 1895), and later Salmon and Ware (1930) and Ware (1939) published evidence of its transmission by grafting. Final proof of its virus origin was, however, obtained only recently (Keyworth and Davies, 1946). The natural agent of transmission is still unknown, but attempts have been made to relate the incidence of Nettlehead outbreaks with certain edaphic factors. The occurrence of a high concentration of plants showing Nettlehead symptoms near hedges, on sites of old hedgerows and on ploughed pasture land has been demonstrated by Duffield (1925), Keyworth and Davies (*loc. cit.*) and Keyworth and Hitchcock (1948). Such an association of Nettlehead symptoms with features in the past history of the land is not invariable, however, and no satisfactory explanation has so far been advanced. It is not yet known whether this apparent concentration of Nettlehead on such sites implies factors influencing either the natural spread of infection or merely the expression of symptoms. Furthermore, attempts to obtain precise information on the possible operation of site factors by correlation with water-table height (Wilson, private communication), and with variations in soil type and in the nutritional status of the hop plant (Tolhurst, 1946) have also yielded inconclusive results.

Against the suggestion that the virus may be widely distributed on such sites and that these edaphic factors merely influence symptom expression, must be set the invariable transmission by grafting, where the appearance of symptoms undoubtedly implies a recent virus infection of the test plant. On this latter assumption are based the results of the survey of a particular outbreak of Nettlehead forming the subject of this paper. Thus, although allowance is made for transient symptom-masking following natural infection, it is generally assumed in this work that a first record of symptoms implies a new infection.

The recorded outbreak.

This paper considers the increase of Nettlehead disease recorded annually from 1948 to 1952 (inclusive) in a garden of Bramling hops in Kent. The plot, comprising 11 rows of 30 hills, was sited to include what was regarded as the primary centre of infection within the hop garden.

Figure 1 shows the development of the disease during each of the five years of the investigation. In this diagram four classes of plants are distinguished: (1) symptomless or healthy, (2) Nettlehead symptoms appearing for the first time in the survey period, (3) Nettlehead symptoms recorded in a previous survey year, and (4) plants which died or were grubbed during this period. For analytical purposes a plant was assumed to be infected from the time of the first recorded symptom until it died or was grubbed, irrespective of any masking of symptoms during the survey period. Conversely, a plant that has not shown Nettlehead symptoms is assumed to have been healthy up to and including the previous year.

Analytical methods and assumptions.

The records were analysed to determine whether or not the spread of this disease was significantly related to the contiguity of infected plants. Two methods of analysis were applied: (1) *temporal*, considering apparent spread from year to year, and (2) *spatial*, considering the distribution of infected and healthy hills in each of five years. The surveyed plot was planted and cultivated on the ' Square Plant ' system, i.e. the hops were planted on a 6 ft. $\times$ 6 ft. lattice and trained up the ' umbrella ' type of stringing. This implies that the stems or ' bines ' of each plant were actually in contact with bines of eight adjacent plants. These latter are subsequently referred to as ' neighbours '. For the purpose of analysis each of the neighbours of an infected hill was thus assumed to have been equally liable to infection.

As there is no direct information on the latent period between natural infection and symptom expression it was assumed for the purpose of the survey to correspond to that following infection by grafting. This is usually 9 to 12 months but occasionally 3 or more years may elapse before symptoms first appear. In one experiment 25 of 37 graft-infected plants developed symptoms in the following year, 3 after 2 years and 1 after 3 years. A latent period of 1 to 3 years was therefore assumed for natural infection and the apparent health status of each of the eight neighbours of an infected plant was considered for 3 years after the latter first showed symptoms.

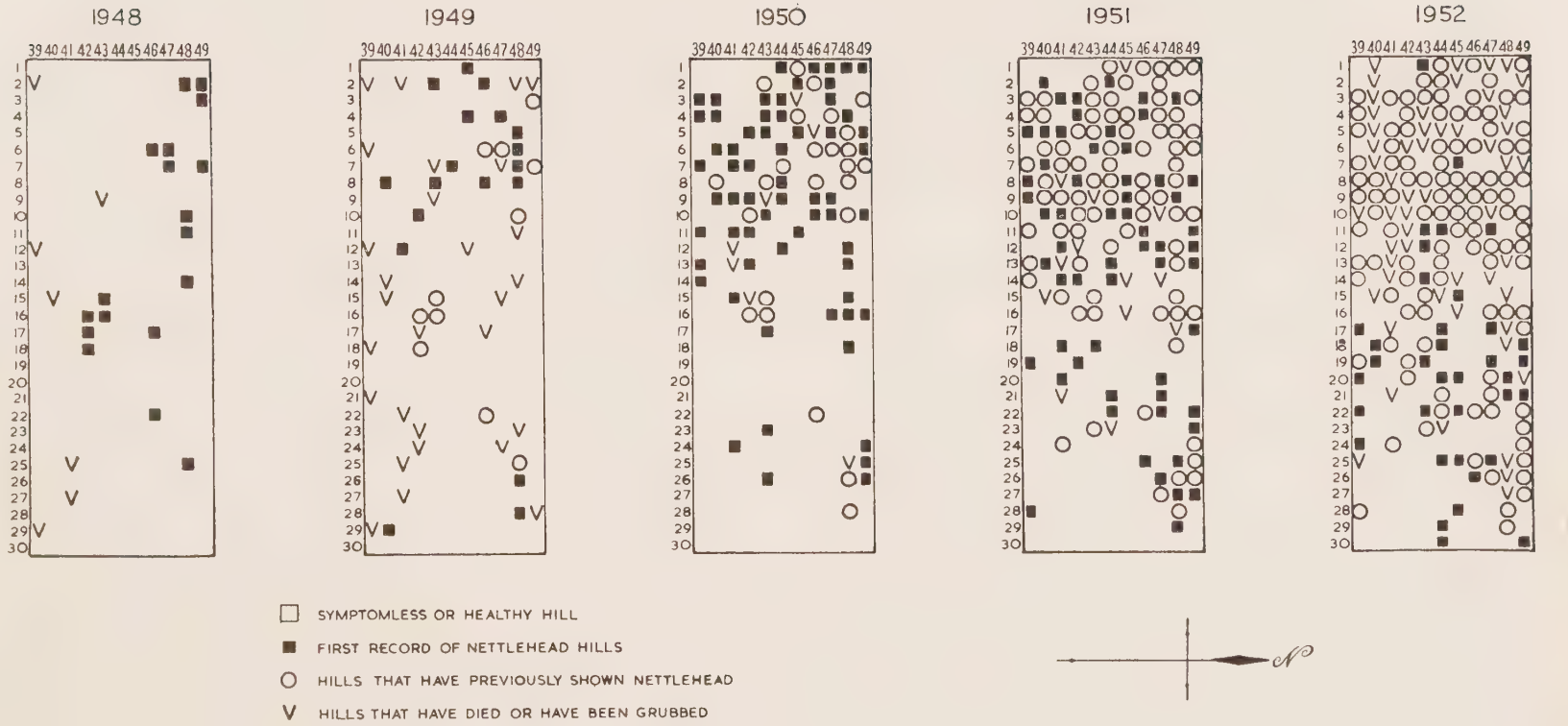

FIG. 1.

The development of Nettlehead on the recorded plot 1948-1952.

The temporal analysis.

The method used is based on the 2×2 comparative trial method of Barnard (1947). For each of the four consecutive years, the apparent Nettlehead-status of every surviving plant (A in Table I) which had shown no symptoms previously was considered in relation to the health of its neighbours (B) in the preceding years, taken singly or together. Each such plant was first classified as (*a*) showing Nettlehead (diseased) or as (*b*) free from Nettlehead (healthy). Plants falling in each of these latter

TABLE I.

CLASSIFICATION OF HEALTHY PLANTS ACCORDING TO (A) THEIR HEALTH IN THE NEXT FOLLOWING YEAR AND (B) THAT OF THEIR NEIGHBOURS IN THE PRECEDING YEARS.

(A) Condition of plants healthy in previous years.				(B) Condition of neighbours in previous years.	
Year.	(*a*) Diseased	(*b*) Healthy			Year.
1949	6	72	$P>0{\cdot}05$	i. Some diseased	1948
	12	201		ii. All healthy	
1950	21	52	$P>0{\cdot}05$	i. Some diseased	1948
	41	175		ii. All healthy	
	35	69	$P<0{\cdot}001$	i. Some diseased	1949
	30	169		ii. All healthy	
	42	88	$P<0{\cdot}001$	i. Some diseased	1948 + 1949
	20	137		ii. All healthy	
1951	18	33	$P>0{\cdot}05$	i. Some diseased	1948
	41	129		ii. All healthy	
	29	42	$P<0{\cdot}001$	i. Some diseased	1949
	30	132		ii. All healthy	
	53	88	$P<0{\cdot}001$	i. Some diseased	1950
	12	90		ii. All healthy	
	51	100	$P<0{\cdot}001$	i. Some diseased	1948 + 1949
	8	74		ii. All healthy	
	53	94	$P<0{\cdot}001$	i. Some diseased	1948 + 1949 + 1950
	6	68		ii. All healthy	
1952	8	32	$P>0{\cdot}05$	i. Some diseased	1949
	27	101		ii. All healthy	
	17	67	$P>0{\cdot}05$	i. Some diseased	1950
	18	69		ii. All healthy	
	30	102	$P>0{\cdot}05$	i. Some diseased	1951
	7	42		ii. All healthy	
	29	104	$P>0{\cdot}05$	i. Some diseased	1950 + 1951
	6	32		ii. All healthy	
	29	106	$P>0{\cdot}05$	i. Some diseased	1949 + 1950 + 1951
	6	27		ii. All healthy	

groups were then subclassified according to the health of their neighbours in previous years as (i) with some diseased neighbours and (ii) all healthy neighbours.

This analysis showed that the distribution of new infections in 1951 was related to the position of plants showing Nettlehead in 1949 and in 1950, and in 1949 and 1950 taken together. No such relationship existed with plants showing Nettlehead in 1948. Further, more of the plants developing symptoms in 1950 and fewer of the remaining healthy plants were adjacent to diseased plants in 1949, and in 1948 and 1949 together, than would have been expected if the apparent incidence of new infections was occurring at random without any relationship to previously diseased plants.

No similar relationship was found for new infections occurring in 1949 and 1952. In the case of 1952 this was probably due to a preferential killing of hills weakened by Mosaic virus and *Verticillium* Wilt disease spreading from the east of the plot, thus reducing the local potential source of Nettlehead infection.

The survival of some ' healthy ' plants surrounded for several years by Nettlehead infected plants may be indicative of some degree of tolerance or resistance towards infection. Some of these plants will be indexed to determine their virus status.

The grubbing of infected hills in the winter of 1949 had no significant effect on the rate of spread of Nettlehead (Table II).

TABLE II.

THE EFFECT OF GRUBBING NETTLEHEAD PLANTS IN 1949 ON THE NUMBER OF INFECTED PLANTS IN 1950.

Diseased neighbours in 1949.	Condition of plants in 1950 that were healthy in 1949.			
	Diseased.	Healthy.	Total.	
Some grubbed ..	6	16	22	$P>0\cdot05$
None grubbed ..	29	53	82	

The spatial analysis.

Each year's records were analysed independently. In Figure 1 healthy plants are shown as white squares and diseased plants in black, and the relative frequency of black-black joins and black-white joins was investigated.

The actual number of black-black joins in 1948, 1950 and 1951 exceeded the number* of these joins which would be expected with a random distribution of black and white (Table III). Conversely there were fewer black-white joins than expected (Table IV).

TABLE III.

THE NUMBER OF PAIRS OF ADJACENT NETTLEHEAD HOP PLANTS (BLACK-BLACK JOINS).

Year.	Observed Number.	Expected Number.	Standard Error.
1948	13	3·4	1·8
1949	8	5·1	2·1
1950	98	62·7	6·5
1951	220	162·0	23·0
1952	54	48·5	6·1

TABLE IV.

THE NUMBER OF PAIRS OF ADJACENT NETTLEHEAD AND HEALTHY HOP PLANTS (BLACK-WHITE JOINS).

Year.	Observed Number.	Expected Number.	Standard Error.
1948	109	121·4	6·2
1949	145	136·3	7·2
1950	328	413·0	13·2
1951	408	524·7	15·8
1952	282	308·8	12·4

* This number was calculated by Freeman using a method based on that of Krishna Iyer (1950).

Discussion.

The results of both methods of analysis give strong evidence of the plant to plant spread of Nettlehead in 1948, 1950 and 1951, and, at a lower level of significance, in 1949 and 1952. Each year there was an increase in the number of Nettlehead plants, new cases occurring more frequently next to already infected plants (black-black joins) as the number of diseased groups of hills increased in each year. This indicates a progressive transportation of the virus from one hop plant to its neighbours. For if some environmental factor had caused the plants to develop symptoms of a latent virus then a simultaneous appearance of the disease would be expected, rather than the annual occurrence of new groups of infected plants.

The distribution of new infections in relation to the disease in the previous years gives some evidence of the length of the latent period between infection and symptom expression. Thus the new infections in 1950 were more directly related to the diseased plants in 1949 than to those in 1948 ($P>0\cdot05$ in 1948, $P<0\cdot001$ in 1949) while in 1951 the distribution of the new cases was related to the Nettlehead plants of the two previous years ($P<0\cdot001$) but not to those of 1948 ($P>0\cdot05$). This indicates that the latent period following natural infection, as in graft-infection, is usually one year, and occasionally two or three years.

Finally, the fact that Nettlehead most frequently spreads to neighbouring plants implies that such spread can be checked if all Nettlehead plants are grubbed immediately they are recognizable.

Acknowledgements.

The writer wishes to thank Messrs. Beeby and Saywell for allowing this trial to be carried out on their farm, and Mr. J. Paine who carried out the initial work.

The writer is also indebted to Mr. G. H. Freeman for the statistical analysis, the results of which form the subject of this paper ; the methods he devised for this purpose will be published elsewhere.

Summary.

A statistical analysis of records for five years of the incidence of Nettlehead virus disease of hops, the vector of which is unknown, showed that the plants immediately adjacent to infected plants were more prone to contract this disease than those more remotely situated.

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PROGRESS IN THE HEAT TREATMENT FOR STRAWBERRY VIRUS DISEASES

By A. F. POSNETTE, R. CROPLEY, and CHRISTINA E. ELLENBERGER

Even the best available stocks of most strawberry varieties are infected with the mild crinkle virus, which is probably an important contributor to the degeneration of plants when they also become infected with other viruses. Because of the rapidity of vegetative propagation, any method of curing individual plants of virus diseases would be valuable, even though it were not applicable on a field scale. Heat treatment is the only method which has given unequivocal results in completely destroying the infectivity of viruses in plants, and immersion of bud-wood in hot water has become a standard nursery technique for the elimination of certain virus diseases of peach. In recent years, prolonged treatment at relatively low temperatures has been more successful than short periods at high temperatures in destroying those viruses with heat inactivation points near the thermal death point of their hosts (Kassanis, 1950, 1952).

Our experiments on different methods of heating strawberry plants started in 1950 with a comparison of warm water with warm air. It was found that young plants, growing in 3-inch pots, completely immersed in water thermostatically controlled at 35° C., survived longer than similar plants treated in the same way but with their roots exposed, and potted afterwards. Potted plants were usually killed after 7 hours in water at 35° C., but in some experiments they survived immersion for 13 hours. These conflicting results were undoubtedly influenced by the condition of the plants before treatment. Well-established plants with roots completely filling the pots survived longer treatments than recently potted plants.

Plants survived up to 7 days heating in an oven thermostatically controlled at 33° C. When the pots were placed in shallow trays containing 1 in. depth of water, it was noticed that roots in the lower part of the pots were killed more quickly than those farther from the water. In an experiment with the variety Huxley's Giant, plants growing in pots standing in trays of water were killed after 3 days in an oven at 33° C., but survived for 6 days when the pots were standing in dry trays.

In these early trials, only plants which survived more than 5 days were virus-tested by grafting to *Fragaria vesca* plants. Despite the high mortality, the results were encouraging—one plant of Perle de Prague induced no symptoms in the test plant and one plant of Huxley induced symptoms of a type much milder than those from any previously tested.

Method of heating.

Young well-rooted plants were prepared for treatment by potting in 3-inch pots at least one month in advance. All leaves but the youngest one were removed, and to reduce damage by fungi, especially *Botrytis cinerea*, the plants were dipped in a proprietary salicylanilide compound immediately before they were put into the incubator. When they were taken out, the plants were twice dusted with 20 per cent pentachlornitrobenzene at weekly intervals. While in the incubator, the plants were examined daily and given water at the same temperature only if the soil was very dry ; it was found that occasional watering to prevent wilting gave better survival than the more frequent watering usually given. The capacity of the incubator was 30 plants, and these were removed, usually in batches of 10, after the required period.

After several days in the oven, the plants became etiolated and the addition of light was an obvious requirement. In 1952, a concrete propagation frame with bottom heat was fitted with double glazing to improve insulation, and with three 500-watt spiral heaters thermostatically controlled. It was found that 37° C. could be maintained with only 2° C. fluctuation. Humidity was high because the floor of the frame was covered with a layer of peat saturated with water before each experiment commenced.

Method of virus-testing.

The treated plants were stored in an insect-proof glasshouse. Following a recovery period of about a month, they were infested with aphids (*Pentatrichopus fragaefolii*) reared on virus-free *Fragaria vesca* plants. After an infection feed of 24 hours, 10 aphids from each plant were transferred to each of two *F. vesca* plants. Unheated control plants in these tests invariably gave virus transmissions.

The heated plants which seemed virus-free were retested by the same method at least 3 months later, and those which again seemed virus-free were grafted to *F. vesca* plants.

Results.

Table I contains a summary of the experiments carried out in 1952. Virus tests which are still incomplete are indicated by question marks in the right-hand column, and virus status is given only when grafts have been completed for a sufficiently long period for symptoms to have developed on the *F. vesca* test plants. Some plants have been recorded as ' virus-free ', a conclusion which may be premature, but is supported by the consistent results of 1952 re-tests of plants similarly heat-treated and recorded in 1951.

TABLE I.

VIRUS INFECTED STRAWBERRY PLANTS SUBJECTED TO A TEMPERATURE OF 37° C. IN FRAME—1952

Variety and virus infection.	Duration in days.	Experiment No.	Number treated.	Number survived.	Virus status.*
Huxley's Giant with Crinkle (Virus 1+3)	5	9	5	5	3 ? Virus-free.
	6	9	5	4	? Virus-free.
	7	1	10	8	Infected
		9	5	5	3 ? Virus-free.
	8	1	10	8	Infected.
		6	10	1	Virus-free.
		9	11	9	6 Virus-free.
	9	1	10	9	2 Virus-free.
		3	10	1	Infected.
		6	10	1	Virus 3 only.
		9	11	9	4 Virus-free.
	10	3	10	2	Infected.
		9	11	9	5 Virus-free.
	11	3	10	2	Virus-free.
Perle de Prague with Mild Crinkle (Virus 1)	7	2	10	8	1 Virus-free.
	8	2	10	9	? Virus-free.
	9	2	10	5	1 Virus-free.
	10	3	10	0	—
	11 & 12	3	20	0	—
Madame Lefebvre with Mild Crinkle and ' Leaf Burn ' (Virus 1+x)	7	2	10	0	
		5	10	1	Virus 1 only.
	8	2, 5, 6	30	0	—
		10	10	10	9 ? Virus-free.
	9	2, 5, 6	30	0	—
		10	10	8	? Virus-free.
	10	10	10	9	? Virus-free.
Early Cambridge with Mild Crinkle and ' Leaf Burn ' (Virus 1+x)	7	5	10	2	Infected.
		8	10	3	Virus-free.
	8	5	10	0	—
		6	10	1	Virus-free.
		8	10	3	Virus-free.
	9	5 & 6	20	0	
		8	10	4	2 Virus-free.

* Not all surviving plants have been tested. ? = aphid test only.

In the incubator apparently complete virus-inactivation has occurred in plants of the varieties Huxley's Giant, Perle de Prague, and Early Cambridge. Tests of Madame Lefebvre are incomplete except for one plant, and in this, one of the viruses present was recorded as inactivated.

The identity of viruses inactivated.

At the start of this investigation it was thought that the Malling clones of Huxley's Giant, Perle de Prague, Madame Lefebvre, and Early Cambridge were infected only with strains of the mild crinkle virus (virus 1 Prentice and Harris, 1946). This seems to be true only of Perle de Prague, in which virus inactivation either was complete or did not occur at all. Some of the heated plants of Huxley's Giant and Madame Lefebvre, however, caused a milder effect on the *F. vesca* plants to which they were

grafted than did untreated plants, and it was clear that the original clones were infected by two viruses, only one of which had been inactivated by the heat treatment.

It is now certain that the stock of M.44 clone of Huxley's Giant used in these experiments contains, in addition to the mild crinkle virus, a second virus which is probably the crinkle virus (virus 3 Prentice, 1949). The new M.49 clone of Madame Lefebvre is known to be infected with an undescribed virus, tentatively named ' Leaf Burn ' or ' x ' in Table I, in addition to virus 1. Virus ' x ' was also found in Early Cambridge.

From the results available so far, it appears that the time required at 37° C. to inactivate virus ' x ' is shorter than that required for virus 1, and that required for virus 1 shorter than that for virus 3. More precise information on time-temperature requirements is not yet available. The yellow-edge virus (virus 2) was not included in these experiments as sufficient material was not available ; a clone of Royal Sovereign with this virus has now been propagated to provide plants for heat treatment.

Special stock propagation.

Foundation stocks of varieties in the Ministry of Agriculture Special Stock certification scheme are raised annually in the insect-proof glasshouse at East Malling. Each parent plant is graft-tested while actually runnering, and, by including heat-treated plants which had already passed two aphid tests and by making the final graft-test in the runner bed, it was possible to raise the 1952 Special Stock nucleus from virus-free plants of Huxley's Giant and Perle de Prague, and from the ' improved ' Madame Lefebvre. These clones will be propagated in isolated Special Stock beds in 1953, and attempts will be made to produce virus-free clones of other varieties. One great advantage of the new virus-free clones is that they need not be isolated during propagation from the virus-free clones of Royal Sovereign and Auchincruive Climax. In fruiting beds where rogueing of infected plants is to be practised, it is still desirable, however, to segregate virus-tolerant from virus-sensitive varieties, since such rogueing would not be practicable in the tolerant varieties ; but segregation when the tolerant varieties are healthy is not so important as when they are already ' carrying ' viruses at planting time.

Summary.

Strawberry viruses of the crinkle types have been inactivated by maintaining plants at 37° C. for 7 to 11 days. Apparently virus-free plants have been propagated after such treatment, and the importance of this is discussed in relation to the Ministry of Agriculture Special Stock Scheme.

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Fig. 1.

Pale yellow rings and lines on the leaves of an apple seedling infected with a virus from plum.

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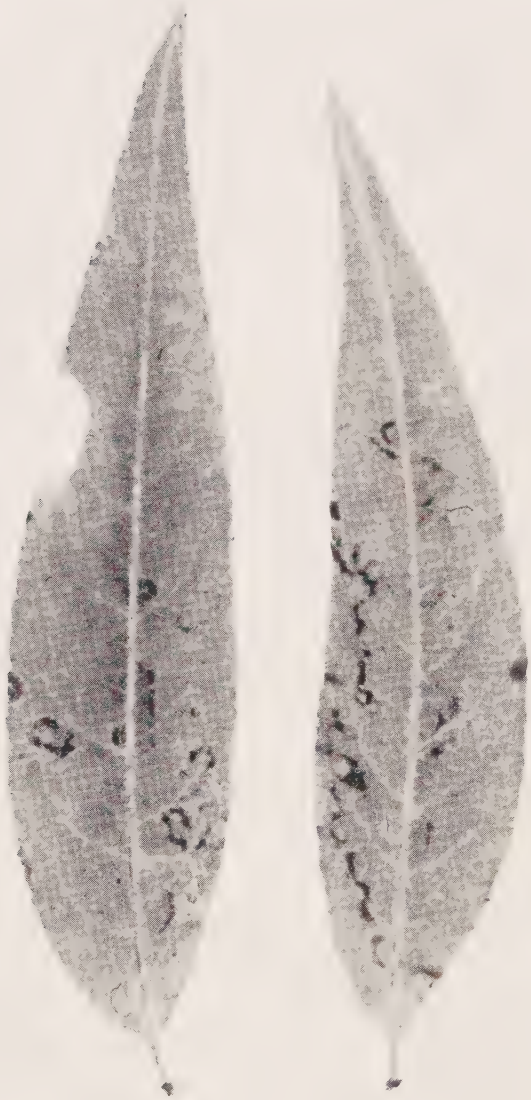

FIG. 2.

Dark purple rings and lines on leaves of a peach seedling infected with a virus from apple.

VIRUS TRANSMISSIONS BETWEEN *PRUNUS* AND *MALUS* SPECIES

By A. F. POSNETTE

As it was thought that some of the viruses infecting apples and pears might also infect peaches, plums, and cherries, and *vice versa*, apple seedlings were included in host-range studies of *Prunus* viruses, and peach and myrobalan plum seedlings in those of apple viruses.

Transmission from plum to apple.

In May, 1951, apple seedlings were inoculated, in sets of six, by chip-budding with rosette virus from cherry (Posnette, 1951) and with four viruses from plum with mosaic, concentric ring spot, vein banding, and line-pattern symptoms (Posnette, 1953). The only plant to show symptoms was one inoculated with concentric ring spot virus, which developed vein clearing in the autumn and, in the following spring, a yellow ring and line pattern (Fig. 1) distinct from the symptoms of any strains of apple mosaic virus studied here (Posnette and Cropley, 1952a). In 1952, the experiment was repeated with a greater number of viruses, and the plum ring spot virus again caused similar symptoms in apple seedlings.

Transmission from apple to peach.

In 1951, peach and myrobalan seedlings, in sets of three, were inoculated by chip-budding with two strains of apple mosaic virus from graft-infected M.IX apple rootstocks, and with chips from a symptomless plant of the M.IX clone. No symptoms have developed on any of the plants inoculated with apple mosaic virus, and back tests to apple indicate so far that the peach and myrobalan seedlings did not become infected. The peach seedlings grafted with chips from the symptomless M.IX all developed leaf symptoms in 1952, however, in the form of dark purple rings and lines (Fig. 2) which had not been recorded previously in experiments with *Prunus* viruses.

Discussion.

As the only latent virus known to have been present in the old M.IX stoolbeds at East Malling is that causing Rubbery Wood (Posnette and Cropley, 1952b), it is suspected that the purple pattern on peach is caused by this virus. If this is confirmed by current tests, using the expressive variety Lord Lambourne, peach will be the best indicator yet found for testing for the presence of rubbery wood virus in apples, where diagnosis is not easy, even in the Lord Lambourne variety, because of the lack of leaf symptoms and of the varying degrees of lignification which occur in the xylem tissues.

Whatever may be the identity of the virus transmitted from apple to peach, these results show that the temporary union formed in grafts between *Prunus* and *Malus* species is adequate for the passage of certain viruses. Better differential indicator plants for the viruses infecting fruit crops may be found by broadening the search beyond the genus in which the virus occurs naturally.

Summary.

A ring spot virus was transmitted by grafting from plum to apple seedlings, causing foliage symptoms distinct from those of apple mosaic.

A virus, possibly that causing Rubbery Wood, was transmitted by grafting from apple to peach seedlings, causing foliage symptoms in the form of purple rings and lines.

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CONCENTRATE SPRAYING IN FRUIT PLANTATIONS: A REVIEW OF EXPERIMENTS WITH LIME-SULPHUR*

By M. H. MOORE

The most recent development in the application of fungicides to fruit trees is that of using smaller quantities per acre of more concentrated sprays than are commonly used in the hydraulic application of dilute sprays by the conventional method. Small droplets of the more or less concentrated fluid, in a fog that may be produced in a variety of ways, are swept up in an air stream at high velocity and propelled through the branches of the trees to deposit the droplets discretely as a protective layer on foliage and fruit.

One question posed is whether or not an effective quantity of the chemical concentrate (dosage) can be as satisfactorily distributed over a given area when carried in a small volume of liquid diluted in, and impelled by, a relatively large volume of air as when diluted in a large volume of liquid and impelled hydraulically. A further question is whether or not the chemical fungicides already known to be reasonably satisfactory for use by the hydraulic method are suitable for this method of air-dispersal.

The advantages of the air-dispersal method lie mainly in a reduction of costs by increasing the speed of treatment, and by eliminating much of the need for supplying and handling water. The main emphasis is on concentration of chemical to compensate for the smaller volume applied. The chief disadvantage of the method is the danger of over-application, which is largely avoided with dilute sprays applied hydraulically because excess spray drips from the tree to the ground.

Choice of fungicide for experiment.

Many materials that have proved satisfactory as dilute sprays have shown promise in the U.S.A. (Garman, 1948 ; Hilborn, 1949 ; Borden, 1952) and in Holland (van den Muijzenberg *et al.*, 1952) for air-dispersal in more concentrated form. Broadly speaking, the concentrate is applied at n times normal strength ($\times n$) and the volume is n times less than normal $\left(\times \frac{1}{n}\right)$ for the dilute spray. For example, a 1 per cent spray at 400 galls./acre becomes a 10 per cent spray at 40 galls./acre.

Hitherto, solid fungicides have been distributed by an air-dispersal method as dusts (e.g. sulphur or copper-lime), but they have suffered the disadvantage of being fairly readily washed off the tree by rain. If solids, such as wettable powders, or concentrated suspensions, such as colloidal preparations, are to prove satisfactory when applied as concentrates at low volume, they must be water-diluted enough to render them readily dispersible ; this sets an upper limit on the concentration at which they can be used, and thus governs the amount of water that must be provided to prepare and distribute them. Moreover, some device for agitating them in the spray-tank must be adopted to keep them in uniform suspension and ensure effective distribution.

The development of safe and effective fungicides soluble in non-phytotoxic oil may eventually prove the most satisfactory method of application, but meantime lime-sulphur offered several advantages for experimental work :

1. Its fungicidal value lies in its soluble sulphides, which, deposited as a liquid, yield a water-insoluble and extremely persistent residue.
2. It is a standard fungicide of proved ability to control Scab (*Venturia* spp.) and Powdery Mildew (*Podosphaera leucotricha*), and it has notable acaricidal properties. This is a valuable combination of attributes, as has become evident during a search for satisfactory substitutes.
3. It is still relatively inexpensive when compared with many of its newer competitors in the high-volume class.
4. Though caustic and somewhat unpleasant to use as a concentrate, it is, nevertheless, not a deadly poison. Highly poisonous materials are obviously to be avoided as concentrate sprays because of their danger to man as drifting clouds of small droplets.

Lime-sulphur concentrate usually contains 24-25 per cent w/v. of polysulphides in solution, and, as it is a free-flowing though sticky liquid, it can be used without further water-dilution. It compares favourably for concentration of active material with, say, a 50 per cent colloidal sulphur diluted $\times 2$,

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which, however, might not prove amenable to satisfactory dispersal. But lime-sulphur diluted to even 1 per cent of the liquid concentrate has sometimes proved phytotoxic, which did not promise well for its safe use when undiluted.

A review of experiments at East Malling.

On small trees.

The first experiment, a phytotoxicity trial on small trees of five apple varieties (Moore, 1948), showed that the undiluted concentrate could safely be applied as a fog of very small droplets (mean diameter of deposit-spots *c.* 40μ) from a paint-gun nozzle attached to an air-compressor.

Since then, atomized 100 per cent and 50 per cent concentrates have been tested over several successive seasons on small bush Cox's Orange Pippin trees on M.IX rootstock. Provided the deposit was not excessive, that is, that most of the individual spots were in the range 50-100μ in diameter, and that they remained discrete (Fig. 1), the application proved safe whether it was made before or after blossoming. Spot-size was somewhat greater with the 50 per cent than with the 100 per cent concentrate. A series of such applications throughout the season proved at least as effective against Scab and Powdery Mildew as the same number of dilute lime-sulphur sprays (2-2½ per cent before and 1 per cent after blossom). The applications in these experiments also were made chiefly from a paint-gun attached to an air-compressor. When a lance with an early type of fixed nozzle designed for atomizing work was used, there was a tendency to apply too much fluid per tree, and scorching resulted on some occasions. A paint-gun nozzle can be adjusted to give a fog to suit the conditions, more air and less liquid being satisfactory for pushing the fog into the trees against a light wind without fear of the over-application that might result from a lower air dilution in those circumstances. A paint-gun was found the most satisfactory means of application for experimental purposes.

Nevertheless, one of the chief difficulties was to apply the deposit uniformly over the trees, and consequently there was a tendency for ' pockets ' of *Venturia* infection to develop here and there on trees that otherwise were well protected and free from infection. The difficulty was naturally enhanced in breezy conditions.

The concentrate dried very quickly after application and was remarkably persistent. The property of small droplets, which have a large surface area in relation to their volume, to dry rapidly is probably the chief reason for their safety on foliage and fruit. In the spring of 1952, 2½ per cent lime-sulphur applied hydraulically caused much more leaf-scorch on comparable trees than the air-dispersed 100 per cent concentrate. This comparison was made without the high delivery pressure for the hydraulic application that can contribute much to spray damage by leaf-bruising. Some evidence was obtained that complete cover of both leaf-surfaces is not necessary for control of *Venturia inaequalis* when lime-sulphur concentrate is used at 100 per cent, but a 10 per cent dilution may fail to give satisfactory control with a similar degree of cover.

It was remarkable how the upper leaf-surface of a spray-sensitive variety (Cox's Orange Pippin) tolerated a really heavy deposit of 100 per cent lime-sulphur without scorching. Some of the older, primary-rosette leaves dropped prematurely after they had received a third application (at petal-fall). This was doubtless a cumulative response, but was not considered a serious matter as these leaves are commonly shed, especially in dry weather, following standard treatments. Many examples of severe leaf-scorch have been seen where the lower surface has received a heavy deposit of the concentrate. This stomatal surface is much more sensitive than the upper, but was not damaged by a light to moderate deposit.

Other fungicides are being tested ; up to the present all those applied in the manner indicated as safe for lime-sulphur concentrate have also proved safe.

On larger trees.

In 1952, machinery became available through the co-operation of the National Institute of Agricultural Engineering (N.I.A.E.), Wrest Park, Silsoe, for extending experiments with 100 per cent lime-sulphur to larger trees, and a trial was undertaken at East Malling Research Station on 30-year-old bush Cox's Orange Pippin trees, with Worcester Pearmain as pollinator. This was supplemented by a few demonstration trials with commercial machines in growers' plantations, in each of which an area was treated with undiluted lime-sulphur, applications being made both before and after blossom on sundry apple varieties at the usual times for hydraulic spraying.

In the Research Station experiment, 100 per cent lime-sulphur at *c.* 10 galls./acre was compared with 50 per cent at *c.* 20 galls./acre. The other comparison was between equal quantities per acre of lime-sulphur concentrate applied (1) hydraulically at 2½ per cent and 2 per cent before blossom and

1 per cent after blossom, and (2) by air dispersal at 10 per cent before and after blossom. Thus, where $2\frac{1}{2}$ per cent was applied at 260 galls./acre, 10 per cent was applied at 65 galls./acre, and so on.*

The Cox trees were planted 24 ft. square with one pollinator in the centre of each square. The large 10 h.p. prototype machine was built to accommodate a fan displacing *c.* 7,600 cu. ft. air/min. at 100 miles/hr. at the circular outlet (20 cm. diameter), fitted with five low-pressure fluid nozzles, and on this closely-planted area it was found difficult with continuous fluid output to manoeuvre the machine far enough away from the trees to treat them uniformly. Branches overhanging the alleys, being too near the outlet, tended to receive excessive fluid, and the leaves on the affected parts of these branches were severely scorched in consequence. A method that the writer had operated successfully at a demonstration of a mist-blowing machine of Dutch manufacture at Bearsted (Kent) in June 1950, was therefore adopted. The fog was directed from the rear of the machine towards the tree to be treated when it was the greatest convenient distance from the outlet and before the jet of fluid was impeded by the overhanging branches of the next tree in the direction of travel. By this means the tree was encompassed by the fog when this had lost much of its directional force and become turbulent, and fairly satisfactory distribution was achieved with *c.* 10 galls./acre of the 100 per cent fluid. Glass microscope slides ($7 \cdot 5 \times 2 \cdot 5$ cm.) were suspended from some of the branches by adhesive paper, and the deposit on the slides could easily be seen, examined, and measured under a microscope ; photographic imprints were readily made from them (Fig. 2). Each tree was treated on two sides from adjacent alleys, and this, theoretically at any rate, should be enough to reach all parts of it with the fog. The powerful air blast generated by the fan was able to force the fog among the foliage and overcome the repelling influence of the prevailing wind. Where the fog was merely drifted into the trees, the cover on the side remote from the breeze tended to be unsatisfactory.

It was soon evident that when the volume of the strong lime-sulphur sprays greatly exceeded 10 gall./acre (144 trees), too much was being applied for safety. Thus 20 galls./acre of 50 per cent fluid was a little more than these trees could tolerate, especially in the early stages of growth, and the higher quantities (30-70 galls./acre) of 10 per cent concentrate proved excessive and productive of much leaf-scorch.

Individual deposit-spots of much greater diameter than 100μ, which had been considered likely to cause damage, in fact proved safe. Evidently a wider size-range of droplets of this caustic spray than had been anticipated could be safely used. Nevertheless, it is sound practice to limit the droplet size within as small a range as can be controlled satisfactorily in the field ; small droplets can provide better distribution over the leaf-surface than larger ones, and are less likely to result in spray damage, though they are not so easily directed and deposited.

Results were encouraging on the commercial farms, where *c.* 10 galls./acre of the 100 per cent concentrate were applied, for no damage ensued except where branches overhanging the alleys received an excess of deposit. The general distribution of deposit was fairly satisfactory, and with the development of improved methods of application, and perhaps some modification in the shape of trees to suit this kind of fungicide dispersal, better results should be possible. It is important to achieve a sufficiently powerful air-blast to reach the tops of the trees.

Data on disease control for these larger trees are not yet available,† but there is evidence to support the results from small trees that 100 per cent lime-sulphur is safe provided it is not applied excessively, and that the right kind of deposit (Fig. 2) can be uniformly distributed over the trees. The problem in the plantation thus largely resolves into one of developing suitable machinery and methods capable of reproducing on a field scale the results achievable in small-scale tests.

Lime-sulphur concentrate is liable to corrode copper or bronze strainers, jets, nozzles, and other parts of spray machinery. Moreover, the dry deposit is inclined to accumulate and block small orifices and spaces between disc-plates, as in some types of fluid outlets that depend on centrifugal force. These should therefore be kept free by frequent washing in water, and all valves, pumps, and other working parts that come into contact with the concentrate must be kept well oiled or greased.

Summary.

Experiments on small Cox's Orange Pippin apple trees have established that 100 per cent and 50 per cent lime-sulphur concentrate can safely and effectively be applied to foliage and fruits when it is uniformly dispersed and deposited in small, discrete droplets in an impelled air stream. Excessive deposit, especially on the lower leaf-surfaces, resulted in severe leaf-scorch. These conclusions are

* The total dosage per acre was about twice as large in the first comparison as in the second.

† Later, the data showed that the higher volumes (including the lower dosages) of spray-fluid per acre gave the best Scab-control and also the most leaf-scorch, which would tend to favour Scab-control by burning existing lesions and causing infected leaves to drop. This contrast between the results from small-scale and large-scale experiments probably arises from the technical difficulties experienced in the plantation and already discussed.

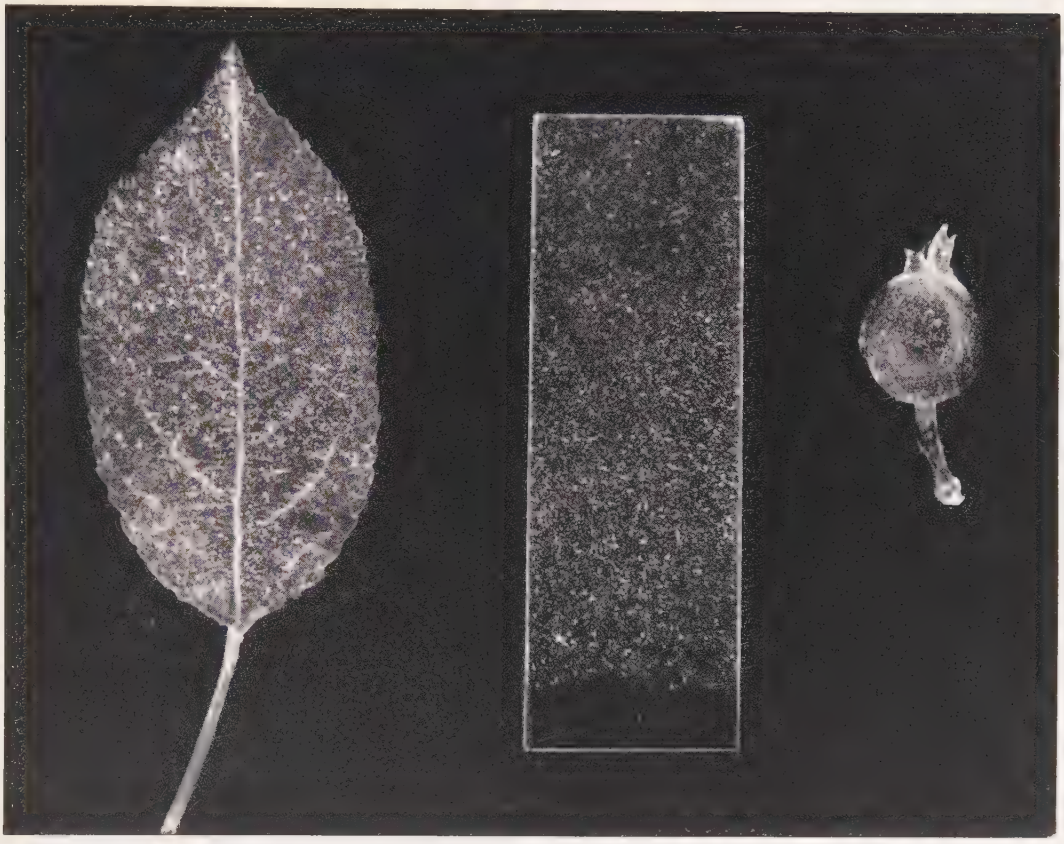

Fig. 1.

Satisfactory deposit from paint gun of 100 per cent lime-sulphur on leaf (slightly rubbed) and fruitlet of Cox's Orange Pippin apple, and on glass microscope slide (7·5 × 2·5 cm.).

Fig. 2.

Deposit from plantation machine of 100 per cent lime-sulphur on glass microscope slide (7·5 × 2·5 cm.) used as photographic negative. Substitution of the largest deposit-spots by smaller ones would be an improvement.

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supported by observations on large trees, where the problem is mainly one of depositing the fungicide in the required manner.

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NOTE ON INFECTION OF BLACKBERRY FRUITS BY THE BROWN ROT FUNGUS, *MONILIA FRUCTIGENA*

By M. H. MOORE and P. W. TALBOYS

In August, 1952, a single fruit bearing pustules of what appeared to be *Monilia fructigena* was found on a bush of the cultivated blackberry, Himalaya Giant (or Himalaya Berry), growing as an escape from cultivation in a commercial pear plantation near Maidstone, Kent. The fruit, which was over-ripe and shrivelled (Fig. 1), was about 6 ft. from the ground on the top of an old spreading tangle of canes growing into a pear tree ; there was ample Brown Rot inoculum on the pears in the vicinity, but a search revealed no more infected berries.

The fungus was isolated in pure culture by streaking a spore-suspension on to prune agar plates and excising some of the resulting individual colonies for transplanting to other plates, and eventually to slopes. Inoculation into apple fruits (varieties Worcester Pearmain and Cox's Orange Pippin) produced typical Brown Rot lesions with pustules in 4-5 days, and eventually the entire fruits rotted (Fig. 2). In culture there was a general tendency to produce microconidia rather than the normal *Monilia*-type spores.

Inoculations.

It proved difficult to sterilize the surface of ripe blackberry fruits for inoculation. In the first attempt on 4th September, healthy berries from the same source as the infected specimen were carefully wiped with cotton wool soaked in absolute alcohol, and mycelium from a tube culture was placed on both needle-pierced and unpierced drupels. No infection by *Monilia* occurred, and both the inoculated and uninoculated series developed contaminants.

In two further experiments, berries contained in Petri dishes were surface-sterilized by exposure to the vapour from propylene oxide absorbed on cotton-wool swabs, following Hansen and Snyder (1947). Treatment was for ten minutes in the first experiment and thirty in the second, after which the dishes were allowed to remain slightly open for ten minutes and for two and a half hours respectively, to allow residual propylene oxide to disperse. High humidity was maintained in the dishes with moist filter paper.

In the first of these two experiments, starting on 16th September, three berries were inoculated by needle directly from pustules on the infected Cox apple fruits into pierced drupels. Three control berries were pierced but not inoculated. Six days later one inoculated berry had developed fluffy *M. fructigena* pustules and one a *Botrytis* contamination, the third remaining healthy. Of the controls, slight contaminants developed on two berries only.

In a final test on 17th September, four berries were wound-inoculated with a spore-suspension made from a pustule on one of the Cox fruits ; wound-inoculations were made also into Cox fruits surface sterilized with absolute alcohol, and there were appropriate controls for each series. Seven days later the inoculated apples had developed characteristic *M. fructigena* infections ; two of the inoculated berries also had developed pustules of this fungus (Fig. 3), and two, slight contaminants. Three berries in the control series developed slight contaminants, but there was no *M. fructigena*. It is possible that the blackberry inoculations were adversely affected to some extent by traces of propylene oxide, a faint odour of which persisted for 24 hours. Some unsterilized berries inoculated directly from pustules through pierced drupels, and kept in the open, freely developed *M. fructigena* pustules as well as contaminants.

Spore measurements.

The following measurements are based on 20 spores in each case :

From blackberry, 25th September (inoc. 16th September).

Range (13·5-26·0 μ) × (11·0-15·0 μ) *Mean* 22·6 × 12·7 μ.

From apple, 25th September (inoc. 17th September).

Range (19·3-27·3 μ) × (12·5-16·5 μ) *Mean* 22·6 × 14·7 μ.

Wormald (1946, p. 59) gives a range (12-34 μ) × (9-15 μ), with a mean about 22 × 13 μ.

Fig. 1.

Himalaya Giant blackberry fruit naturally infected with *Monilia fructigena*. (enlarged *c.* × 4).

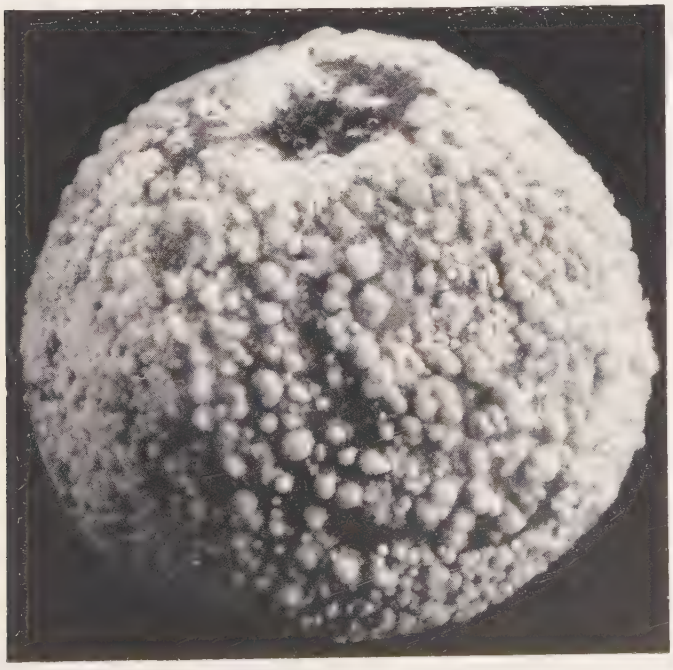

Fig. 2.

Characteristic Brown Rot infection on Cox's Orange Pippin apple fruit inoculated with fungus isolated from fruit shown in Fig. 1.

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FIG. 3.

Himalaya Giant blackberry fruit inoculated with spore-suspension obtained from apple fruit in Fig. 2. (enlarged *c.* ×4).

Discussion.

Monilia fructigena evidently is a pathogen of the Himalaya Giant blackberry fruit, though not a common one. The writers have not seen any reference elsewhere to the pathogenicity of the fungus on this host, and it is clearly unlikely to be of economic importance as such. But it appears that one more is added to the already long list of hosts of this disease in this country, and therefore to the list of possible sources of infection for other, more important, hosts. This in turn has a bearing on the difficult problem of eradicating sources of infection for commercially valuable fruit crops by measures of general hygiene, or possibly by the use of eradicant sprays (Byrde, 1952).

Summary.

Monilia fructigena is recorded as a pathogen of the cultivated blackberry, Himalaya Giant. An isolate from blackberry caused characteristic Brown Rot symptoms when inoculated into apple fruits, and blackberry fruits were likewise infected by an isolate from the apple.

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A PRELIMINARY NOTE ON METHODS FOR OBTAINING BACTERIA-FREE EELWORMS

By J. E. CROSSE and R. S. PITCHER

The problem of freeing living nematodes from attendant or adherent micro-organisms has received some attention from workers on the nutrition of animal parasites, who have evolved several successful but rather complex techniques for their sterilization. Workers on plant parasitic nematodes, concerned principally with etiological or taxonomic problems, have not found the need of sterile material to be so pressing and it appears that little work has been done in this field. Christie and Crossman (1936), writing on the plate culture of two races of *Aphelenchoides fragariae* (now known to be *A. besseyi* and *A. fragariae*) recommend a preliminary surface sterilization in mercuric chloride at 0·05 per cent for 30 minutes. This treatment was said to have no adverse effect on *A. besseyi* and comparatively little on *A. fragariae*. Dr. J. W. Seinhorst has reported (verbal communication) that certain organic mercurial compounds will greatly reduce the microflora without harm to *Ditylenchus dipsaci* and other species. Sodium hypochlorite, often in a proprietary formulation, has been used successfully by several workers for the larvae of *Meloidogyne* and *Heterodera* spp. Saprophagous nematodes may have a considerable intestinal microflora and the techniques evolved for their sterilization have been more lengthy and complex. Dougherty and Calhoun (1948) used penicillin, streptomycin, and merthiolate prior to the artificial culture of *Rhabditis pellio* ; Zimmerman (1921) immersed the vinegar eelworm, *Turbatrix aceti* (Müller, 1783) var. *aceti* Peters, 1927, twice daily in hydrogen peroxide for ten successive days.

The authors' attention was directed to this problem during the course of a recent etiological investigation of Cauliflower disease of strawberry (Crosse and Pitcher, 1952) in which two organisms, an eelworm, *Aphelenchoides ritzema-bosi* (Schwartz, 1911) Steiner, 1932, and a bacterium, *Corynebacterium fascians* (Tilford) Dowson, had to be considered. Prior experience had shown that eelworms obtained from strawberry plants were often heavily contaminated with bacteria, which on occasion formed virtually a complete sheath around the nematode. It was therefore of fundamental importance that these contaminants be eliminated before experimental inoculations of eelworms and bacteria, separately and together, could be carried out. Mercuric chloride, as used by Christie and Crossman on other species of *Aphelenchoides*, proved to be highly toxic to *A. ritzema-bosi*.

Preliminary tests with various other sterilants were therefore begun to estimate their relative nematicidal and bactericidal activity and to evolve suitable methods of using them. On the basis of these results promising sterilants and methods were selected for more critical examination in a series of intensive tests. The results of this investigation are described below.

Methods and materials.

One eelworm species, *Aphelenchoides ritzema-bosi*, freshly isolated from strawberry plants or dried chrysanthemum leaves, was used throughout the experiments. The following range of sterilants was tested :—mercuric chloride, silver nitrate, sodium hypochlorite, copper sulphate, ethoxyethyl mercury chloride, 8-hydroxyquinoline sulphate and 8-hydroxyquinoline potassium sulphate. The test procedure was as follows :—a quantity of eelworms was immersed in a given concentration of sterilant contained in a sterile petri dish and, after a predetermined exposure time, divided into two parts. One half was used for viability counts, while the eelworms in the other were centrifuged, washed four times with sterile distilled water, left overnight, washed twice more and then tested for sterility. Control batches were immersed in sterile distilled water and similarly treated. In the early tests it was noted that certain sterilants showed a delayed toxicity resulting in a further loss in eelworm viability after washing. In later tests, therefore, this effect was measured by two separate estimates of viability, an ' immediate viability ' count, made soon after the withdrawal of sterility samples, and a ' final viability ' count, made not less than 24 hours after washing and transfer to sterile distilled water.

Sterility was tested by suspending eelworms in molten nutrient agar, plus 5 per cent sucrose, and plating. After six days' incubation at 25° C. bacterial colony counts were made and compared with control plates containing unsterilized eelworms. Sterile water ' blanks ' were included to check the number of incidental contaminants collected during the washing process.

Preliminary tests.

The classical sterilants, mercuric chloride, silver nitrate, and sodium hypochlorite, were tested first. These were employed at concentrations of 0·05-0·1 per cent, 1 per cent, and 3·5 per cent, respectively, and at exposure times of from 3 to 20 minutes. Silver nitrate and sodium hypochlorite were highly toxic to the eelworms at all exposure times and were discarded as it was considered unlikely that reduced concentrations would give a satisfactory degree of sterility. Copper sulphate was subsequently rejected for similar reasons. The lower concentrations of mercuric chloride were more promising and were therefore reserved for further tests.

Initial tests of an organic fungicide, ethoxyethyl mercury chloride, in the form of a proprietary compound containing 3 per cent of this agent with sodium bicarbonate as a filler, gave promising results. This compound was used in concentrations ranging from 0·003 to 0·000375 per cent of the active agent. Exposure to the higher concentrations for 15-60 minutes gave inconsistent results, but prolonged exposure (40-90 hours) to the lower concentrations gave a high degree of sterility without any marked loss of eelworm viability. Tests of a similar nature with low concentrations of mercuric chloride gave comparable results. It appeared likely, therefore, that methods based on the use of relatively low concentrations for long periods would prove most satisfactory.

In one test with ethoxyethyl mercury chloride the detergent dioctyl sodium sulphosuccinate was added in an attempt to secure a more even wetting of the eelworm surfaces. There were indications that the detergent brought about an increase in the general level of sterility and tended to reduce variation between replicates. Detergents of this type are well known to have a synergistic effect on the activity of certain bactericides (Tobie and Orr, 1945) and the detergent was therefore added to all sterilants in subsequent tests.

Intensive tests.

On the basis of the preliminary results mercuric chloride and ethoxyethyl mercury chloride were selected for further testing. The initial success with the latter compound prompted the inclusion of two other organic compounds, 8-hydroxyquinoline sulphate and 8-hydroxyquinoline potassium sulphate. All sterilants were tested at comparatively low concentrations and in the presence of 0·01 per cent dioctyl sodium sulphosuccinate.

Hitherto the exposure time had been decided more or less arbitrarily ; from the point of view of sterility, however, it was desirable that exposure times be as long as possible. A series of independent nematicidal tests were therefore made to find how long eelworms would withstand the various treatments without appreciable loss of viability. Eelworms were immersed in the sterilants as before and a series of viability counts made over a period of 3-4 days. For each concentration of sterilant the ' maximum exposure time ' was then estimated, this being the longest exposure time possible without incurring an immediate loss in eelworm viability of more than 5 per cent.

The sterilants were then retested on fresh samples of eelworms using actual exposure times based on the estimated ' maximum exposure times '. Sterility tests were made on aliquots of each replicate using a slightly modified procedure. Before plating, the eelworms were collected in the bottom of the centrifuge tubes in a minimum of water, covered with sterile carborundum powder and macerated by pressing a flattened glass rod on top of the carborundum and rotating it. The remainder of each replicate was used for the immediate and final viability counts.

The results of two series of tests are shown in Table I. The figures for percentage viability and sterility are averages for four replicates. In the sterility tests there were approximately 200 eelworms in each plate poured.

It is evident that all treatments gave a considerable reduction in bacterial flora as compared with the controls, amounting in most cases to complete sterility when the incidental contaminants, as shown by the sterile water blanks, are taken into account. The higher concentrations of mercuric chloride gave marked evidence of delayed toxicity which was not consistent from test to test (e.g. 0·0004 per cent). Ethoxyethyl mercury chloride, however, repeated the satisfactory results obtained in the preliminary tests.

Discussion.

In both preliminary and intensive tests it proved difficult to find concentration/time combinations of inorganic compounds which would give an adequate degree of sterility without harming the nematodes. This difficulty was increased by the inconsistent behaviour of those treatments which showed initial promise (e.g. mercuric chloride). It was relatively easy, however, to obtain acceptable levels of sterility and viability with the organic compounds tested and, in the case of ethoxyethyl mercury

TABLE I.

EELWORM VIABILITY AND STERILITY TESTS.

Sterilant.	Concentration (per cent).	Exposure time (hours).	Percentage eelworm viability.		Sterility (No. bacterial colonies isolated).
			Immediate.	Final.	
Experiment 1.					
Mercuric chloride	0·004	15	98	34	4
,,	0·0014	27	98	55	1
,,	0·0004	45	100	94	4
,,	0·00014	90	97	97	100
,,	0·00004	90	96	96	numerous*
Ethoxyethyl mercury chloride	0·000375	90	97	96	9
Control		90	96	93	77,200†
Sterile water blank		—	—	—	3
Experiment 2.					
Mercuric chloride	0·0004	48	72	9	0·25
8-hydroxyquinoline sulphate	0·1	72	91	86	0·5
8-hydroxyquinoline potassium sulphate	0·5	90	96	92	1·0
Ethoxyethyl mercury chloride	0·000375	72	99	99	0·5
		90	98	96	0·5
Control		90	99	99	15,900·0†
Sterile water blank		—	—	—	1·75

* Plates covered by spreading bacteria, making individual colony counts unreliable.

† Estimated from dilution counts.

chloride at least, to achieve consistent results. The safety margin between bactericidal and nematicidal activity appeared to increase as concentration decreased until, at very low levels, the eelworms would tolerate almost indefinitely a solution which was still bactericidal. The long immersion times required with low concentrations allow better control of the sterilization process, since the end-points at which satisfactory sterility and viability are obtained are far less critical. Eelworms pre-sterilized with ethoxyethyl mercury chloride have been repeatedly used for the successful inoculation of strawberry plants and 8-hydroxyquinoline potassium sulphate gave equally satisfactory results on the only occasion on which it was tested.

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Summary.

An investigation has been made of methods of freeing the eelworm *Aphelenchoides ritzema-bosi* from bacterial contaminants by the use of chemical sterilants. Best results were achieved by immersion in low concentrations of organic compounds for periods up to 90 hours.

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ENTOMOLOGY

THE EFFECT OF SPRAYING MATERIALS ON SOME PREDATORY INSECTS

By ELSIE COLLYER

The increase of the Fruit Tree Red Spider Mite in commercial orchards appears to have been due mainly to the detrimental effect that spray materials used against pests and diseases, including the red spider mite itself, have on the predatory insects and mites. Some workers (DeBach, 1947 ; Kuenen, 1946) consider that a direct physiological effect also occurs, causing the mites to breed more rapidly in the presence of spray residues. If indeed this factor is at work, then it is in addition to the increase in mites which occurs when their predators are reduced.

During the past six years observations have been made in many commercial orchards in Essex on the effects of routine sprays on predators ; detailed counts have been made on experimental plots where spraying trials* against the Fruit Tree Red Spider Mite have been carried out. These observations have been made in orchards which have been sprayed for many years, and do not relate to the initial effect of the various insecticides upon the complex of predators which, in unsprayed orchards, keep the mite at a very low density.

Winter washes.

There is much evidence to show that winter washes have a harmful effect on predators of the Fruit Tree Red Spider Mite. In Europe Massee and Steer (1929) noted the increase of the mite as a result of tar distillate washes killing *Anthocoris nemorum* L. Since then many Continental workers have noted the harmful effect of both tar oil and DNC washes on overwintering Anthocorids and Coccinellids (Andersen, 1948 ; Geijskes, 1938 ; Günthart, 1945 ; Speyer, 1934).

Effect of winter washes on the Black-kneed Capsid.

When the study of predators in Essex commenced, nothing was known of the effect of spray materials on *Blepharidopterus angulatus* (Fall.), the Black-kneed Capsid, as it had not previously been recognized as a beneficial species. Its general abundance in orchards which received a routine application of tar oil, in many cases followed by a spring application of DNC, indicated that these washes did not have a very great effect on the overwintering eggs of this insect.

In the winter 1946-7 a spraying trial was started at Writtle, in Essex ; winter petroleum oil was applied on 17th March against the winter eggs of the Fruit Tree Red Spider Mite, only lead arsenate and nicotine being used in the following summer. Beating records of Black-kneed Capsid nymphs were taken on 23rd June, when the majority had hatched but none had reached the adult stage. Two trees were beaten from each plot, there being five replicates of each treatment. The totals obtained are given in Table I. No significant differences were found between the number of Black-kneed Capsid nymphs on the four treatments, or between the means of sprayed and unsprayed plots.

TABLE I.

EFFECT OF WINTER PETROLEUM OIL ON BLACK-KNEED CAPSID EGGS, 1947.

	Number of nymphs from eight trees.
Unsprayed	160
3% stock emulsion	84
5% stock emulsion	107
3% miscible oil	168
5% miscible oil	109

* Trials carried out under the auspices of the A.R.C.-Pettar-Ace Fruit Tree Red Spider Investigation.

In 1948 and 1949 further experiments were made at Great Braxted, Essex, to study the effect of routine winter washes upon the eggs of the Black-kneed Capsid. In 1948 the following treatments were compared : 6 per cent tar oil, 15th January ; 3 per cent petroleum, 4th February ; 3 per cent DNC/petroleum, 4th February ; 3 per cent petroleum, 22nd March ; 3 per cent DNC/petroleum, 22nd March ; unsprayed. The total Black-kneed Capsid nymphs per tree were estimated in the summer ; no significant differences occurred between treatments.

In 1949 the four treatments were : 6 per cent tar oil, 14th January ; $4\frac{1}{2}$ per cent DNC/petroleum, 22nd March ; $4\frac{1}{2}$ per cent petroleum, 22nd March ; unsprayed. The trees were larger than those used in the previous year ; it being impossible to obtain the total numbers of nymphs per tree, several other methods of recording were used. Observations on a small number of marked eggs showed that about the same percentage hatched under all treatments, but later beating records gave smaller numbers of nymphs on the DNC/petroleum trees than on the other three treatments. It is probable that the DNC/petroleum prevented some of the Fruit Tree Red Spider Mite winter eggs hatching, and that the lower mite population on these trees resulted in a higher natural mortality of Black-kneed Capsid nymphs.

Effect of winter washes on Coniopterygids.

In some years, particularly when the summer is warm and dry, *Conwentzia pineticola* End. (Neuroptera, Coniopterygidae) becomes abundant in orchards. It overwinters in the prepupal stage inside a white cocoon spun on the trunk or branches of the trees, but frequently the insect is not to be found early in the following year. During the winter 1947-8 cocoons collected from various sources were kept under observation at the time of emergence. Table II shows that considerable mortality was caused by tar oil and DNC washes.

TABLE II.

EFFECT OF WINTER WASHES ON CONIOPTERYGID COCOONS.

Treatment.	Total number of cocoons.	Number emerged.	Per cent emerged.
Unsprayed	168	96	57
Tar oil only	81	5	6
Tar oil and DNC/petroleum ..	50	1	2

Summer washes.

There is little published evidence of a conclusive nature regarding the effects on predators of the Fruit Tree Red Spider Mite of the many sprays used during the growing season to control pests and diseases, except in the case of DDT, references to which are too numerous to detail. Gilliatt (1935) mentioned that immature capsids were killed by nicotine, whereas the Ladybird, *Stethorus punctillum*, was not. Günthart (1945) and Lord (1949) discuss the effect of many of the long established summer washes on phytophagous and predacious mites and their insect predators.

Lime-sulphur and nicotine.

Lime-sulphur is the principal fungicide used in England. It kills predacious mites of the family Laelaptidae, which are therefore rarely abundant in this country in commercial orchards. In North America, where copper fungicides are used, these mites play an important part in reducing red spider mite numbers (Lord, 1949). Lime-sulphur has very little effect on the *insect* predators, although it kills a small percentage of young Black-kneed Capsid nymphs ; repeated applications after the end of May can cause a considerable reduction in its numbers. Nicotine, although it kills some recently hatched Black-kneed Capsid nymphs, only results in the mortality of a small percentage of this insect.

Derris.

Derris was used widely as an acaricide before the development of the organophosphorus insecticides. At Goat Lodge Farm, Great Totham, Essex, a trial was carried out in 1947 comparing the effects of various sprays on the red spider mite. One per cent lime-sulphur and 1 per cent summer petroleum were applied to different plots on 2nd June, and on 18th June half of each of these plots received an application of derris (0·004 per cent rotenone) in summer petroleum (0·5 per cent). The derris in oil had a considerable effect upon the Black-kneed Capsid, which had hatched abundantly throughout the orchard. When a beating record was taken on 14th July there was a total of 33 nymphs

on the derris in oil plots, and 262 on the others. That season derris was used extensively in commercial orchards as a wettable powder (0·004 per cent rotenone) ; it was found to kill many of the recently hatched nymphs, although it did not cause such a high mortality as derris in oil.

DDT.

Since the introduction of DDT, workers from all parts of the world have reported an increase in the Fruit Tree Red Spider Mite and related phytophagous mites following its use. Most workers agree that this effect is due to the killing of predators, although it has been suggested that other factors may also be at work.

DDT applied in any form is toxic to all common insect predators of the red spider mite, but the residual toxicity causes an even more rapid increase of the mites by killing all incoming predators for a considerable time after the application. The duration of the residual toxicity varies with the formulation of DDT, and with the different insect species and their stage of development. The early work in England suggested that it was safe for use up to the green cluster stage on apple ; these early applications killed the Anthocorids when they became active in the spring, but, as most orchards received a routine winter wash, the number of such species emerging was, in any case, small. The period which elapsed between the green cluster DDT and the beginning of the hatching of the Black-kneed Capsid nymphs was always over six weeks, by which time the DDT had lost its residual toxicity.

In 1948 an experiment was carried out with DDT at Lealane Wood Fruit Farm, Great Braxted, Essex. 100 trees of Cox's Orange Pippin were divided into a number of plots and 0·05 per cent DDT applied at various times. Mite records were taken, but, due to a combination of high mite populations and small plots, a uniform infestation developed over the whole orchard. The two predators present in abundance were the Black-kneed Capsid, which was still immature and therefore had only a limited ability to move from tree to tree, and *Orius majusculus* (Reut.), all stages of which were present. DDT at petal-fall and later had a considerable effect on both these species of predator, and the application on 8th April had some effect also (Table III). When DDT is used there is a reduction of predators, particularly very active ones, on neighbouring unsprayed trees, and this may partly account for the fact that mites built up so rapidly on all trees.

TABLE III.

EFFECT OF DDT ON *Blepharidopterus angulatus* AND *Orius majusculus*, 1948.

Treatment.	Dates of application of DDT (0·05%) and derris (0·004% rotenone).	Numbers per tree obtained by beating.			
		24th June.		22nd July.	
		B. angulatus.	*O. majusculus.*	*B. angulatus.*	*O. majusculus.*
Routine lime-sulphur only ..		20	30	24 19	40 30
Routine lime-sulphur and two applications of derris ..	1st and 14th June			5	30
Routine lime-sulphur with DDT in 2% lime-sulphur at green cluster	8th April	6	1	12	25
DDT in 2% lime-sulphur at green cluster and two applications of derris	8th April 1st and 14th June			3	8
Routine lime-sulphur with DDT in ¾% lime-sulphur at petal-fall	13th May	2	20	1	1
DDT	7th June	2	0	0	2
DDT	25th June	20	55	0	1

In 1949 a block of sixteen trees was sprayed with wettable DDT at the rate of 2½ lb. per 100 gallons on 1st July ; it had an average population of both red spider mites and Black-kneed Capsid nymphs. The red spider mite population gradually declined, and the leaves remained green on the trees not sprayed with DDT ; on the trees sprayed with DDT all the Black-kneed Capsid nymphs were dead within four days. No predators were present on these trees until the end of July, when a few *Anthocoris nemorum* L. and *Orius majusculus* (Reut.) began to return. The Fruit Tree Red Spider Mite increased rapidly ; leaf bronzing was severe by 19th August and defoliation occurred in September. A count of mites made by the 'imprint method' on 4th August showed that there was an average of one mite per leaf on the unsprayed trees, and 192 mites per leaf on the trees sprayed with DDT.

BHC.

During 1950 a small experiment was carried out at Porter's Farm, Great Braxted, to determine the residual effect of BHC against the more common species of predatory insects. The application was made on 26th June while the Black-kneed Capsids were still immature, and other predatory species were becoming numerous. Three groups of small Laxton's Superb apple trees were sprayed with 50 per cent BHC wettable powder at the rate of 4 lb., 2 lb., and 1 lb. to the 100 gallons respectively. Groundsheets were placed beneath the trees, and more predators liberated on to the trees at intervals after the application. All the important species of insect predators of the Fruit Tree Red Spider Mite were affected by the application of all the concentrations, but the residual effect differed appreciably with the various species. Little residual effect was shown towards adult *Stethorus punctillum* (Wei.) and even less towards the larvae, a few of which survived the initial applications of 1 lb. and 2 lb. per 100 gallons sprays ; 4 lb. per 100 gallons was effective against the adults for one or two days. The predacious Hemiptera, including the Black-kneed Capsid, *Anthocoris nemorum* L. and *Orius majusculus* (Reut.), and the Rove beetle, *Oligota flavicornis* Boisd., were far more susceptible, in both adult and immature stages. BHC at 4 lb. per 100 gallons was toxic towards these species for sixteen days, at 2 lb. for fourteen days, and at 1 lb. for about seven days.

Parathion.

Parathion and other organo-phosphorus insecticides are now used extensively on fruit trees. Although parathion is used as an acaricide, its use is followed by a rapid increase of mites, similar to that which follows the use of DDT, although it is delayed for several weeks following the initial destruction of mites. Predators are eliminated and the residual toxicity affects many species although having little effect on the Fruit Tree Red Spider Mites. An example of the effect on the predator and mite populations of the use of parathion as an acaricide has been discussed elsewhere (Collyer, in the press).

All the important predators of the Fruit Tree Red Spider Mite are killed where parathion is used at the usual strength of 0·01 per cent. In 1949 parathion was applied experimentally on 1st June at the unusual strength of 0·06 per cent on a summer acaricide spraying trial at Writtle, Essex. The Black-kneed Capsid started hatching in June, and continued on the control trees until well after the final record was made on 14th July (Table IV), whereas the numbers which survived on the sprayed trees were negligible.

TABLE IV.

EFFECT OF PARATHION ON *B. angulatus*.

Treatment.	Date of application.	Number of nymphs per tree.	
		8th June.	14th July.
Unsprayed	1st June	708	813
Parathion 0·06%		1	13

The residual effect of 0·06 per cent parathion on the hatching Black-kneed Capsids was thus over six weeks. The effect was not ovicidal, as eggs could be seen hatching, and the young nymphs walking up the twigs for an hour or so before falling off paralysed. The residual toxicity of the recommended strength of 0·01 per cent is considerably less. Black-kneed Capsids which are hatching all die for at least a fortnight after the application, and many examples have been seen of them dying up to twenty days after. Plants are toxic for at least ten days to adults of the Black-kneed Capsid, of other Miridae and of the Anthocoridae flying on to the trees. There is a similar effect upon *Stethorus punctillum* Wei. and *Oligota flavicornis* Boisd., but adults of *Coccinella septempunctata* L. survive when placed on foliage two to three days after spraying.

Summary.

An account is given of the effect of various spray materials on the more important predators of the Fruit Tree Red Spider Mite. Routine winter oil applications have no appreciable effect on the eggs of the Black-kneed Capsid, *Blepharidopterus angulatus* (Fall.), although they kill adults of several species of hibernating predators. The effects of lime-sulphur, nicotine, derris, DDT, BHC, and parathion on various predator species are discussed, and details given of the residual toxicity of the last three sprays.

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NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1952

By A. M. MASSEE

1. Flax Flea Beetle (*Longitarsus parvulus* Payk.).

The minute, black, Flax Flea Beetle occurred in numbers on cherry foliage at the Research Station, and in other cherry orchards at East Malling at the end of May. This species was also found on apple foliage in a commercial plantation at Maidstone about the same period. The feeding was confined to the upper surfaces of cherry and apple foliage, and, although the feeding areas were apparent, the injury was not serious. This species is now widely distributed in Kent during the summer months, and is attached to a wide range of host plants. The Flax Flea Beetle has only become generally common in recent years, and until the last war it was regarded as one of the rarer species of the genus *Longitarsus*, and was not represented in many collections.

The Flax Flea Beetle is the second species to be recorded on top fruit ; a few years ago, in 1944, a closely allied species, *Aphthona euphorbiae* Sk., was observed feeding on apple foliage in Essex.

From time to time new records are obtained of insects associating themselves with cultivated fruits, and, provided there is evidence of their feeding on the foliage or on other parts of the tree, brief details are mentioned in these notes.

2. Clay-coloured Weevil (*Otiorrhynchus singularis* L.).

The Clay-coloured Weevil is a pest of considerable importance on top and soft fruits, not only because it infests a wide range of host plants, but also because it may cause widely different kinds of damage on the various hosts. For instance, a new kind of injury was noted on Conference pear during the latter part of May at Cooling, Ryarsh, and Maidstone, Kent. The adult weevils were observed feeding on the stalks of the fruitlets, frequently decapitating them, and leaving the stems poised upright in mid air. This kind of injury was very extensive in the plantation at Cooling, and, as is usual with this species, the feeding was confined to the period of darkness. This type of injury has been observed for many years, but the true cause of the damage was not discovered until this year.

3. Apple and Plum Casebearer (*Coleophora nigricella* Steph.).

The Apple and Plum Casebearer, as its name implies, is more plentiful on apple and plum than other top fruits, but at the end of April an exceptionally severe infestation was noted on sweet cherry in an orchard at East Malling. The small larvae, in their cigar-like cases, were feeding on the buds, and could be found in their thousands in well sheltered and protected situations on the trees. Several larvae occurred on a single bud, causing much injury and stunting of the buds and growths. As the leaves opened the larvae moved on to them and fed on the upper surfaces, eating the epidermis.

It is curious that this species was not seen in the orchard last season ; it may have been present in small numbers, and thereby overlooked. Worcester Pearmain and Beauty of Bath apples growing in an adjacent orchard were infested by the same species of Casebearer, but the injury was less extensive.

An application of 0·1 per cent DDT applied at the end of May very effectively controlled this pest.

4. Geometridae and Tortricidae species.

The caterpillars of several species of the Winter Moth group and the *Tortricidae* were more prevalent than for several years past in many orchards in the Maidstone district and in North Kent. The increase generally occurred in the apple, pear, and plum orchards where pre-blossom sprays of DDT were not used, and where post-blossom phosphorus insecticides were omitted from the spray programme. The Winter Moth and the Fruit Tree Tortrix Moth (*Cacoecia oporana* L.) were the commonest species in most orchards, but several other kinds were represented in smaller numbers. It is not considered that the caterpillars were causing much harm to the trees, but, in view of the very low populations noted in commercial fruit orchards these days, even a slight increase is readily detected by the keen grower.

5. Small Ermine Moth (*Yponomeuta padella malinella* Zell.).

The widespread distribution of the Small Ermine Moth in apple and plum orchards in many parts of Kent again this season is difficult to account for. The pest has been noted commonly at Canterbury,

Deal, East Malling, Faversham, Maidstone, Marden, Sandwich, Sevenoaks, and Staplehurst, in Kent. It was prevalent also in orchards of East Sussex and Essex.

Thirty years ago the Small Ermine Moth was a familiar pest in most commercial orchards, and the general decline in recent years has been directly attributed to the routine applications of tar oil washes. If this deduction is correct it is difficult to account for the return of the Small Ermine Moth in apple and plum orchards at the present time. One curious fact is that it has been plentiful in orchards which have been sprayed with tar oil and also in those which have received a DNC/petroleum spray. It has also been found on unsprayed trees in cottage gardens.

A possible explanation may be that many orchards to-day are sprayed by means of mobile machines, and the spray coverage is often indifferent ; thus many of the overwintering larvae and egg masses may escape the spray application.

6. Buff Ermine Moth (*Spilosoma lubricipeda* L.).

Unfamiliar species of caterpillars are noted feeding on the foliage of fruit trees most years, but this season has been exceptional for the number of different larvae feeding on the foliage of top fruits. Amongst these was the caterpillar of the Buff Ermine Moth. This species is usually associated with low-growing plants, and various species of weeds. It is a particularly common species in gardens where the larvae feed on various herbaceous plants and ferns.

The Buff Ermine Moth was locally common in several apple orchards around Chelmsford and Witham, Essex. The larvae were feeding on the leaves of the new growths, and were plentiful from the end of June onwards. Dessert varieties seemed more subject to attack, but further information is required to confirm this observation. The newly hatched caterpillar is pale yellowish ; later instars are more greyish or brownish, with short and bristly pale hairs, with a whitish line along each side. The caterpillar becomes very active when disturbed. It feeds from the latter part of June until September. The red-brown chrysalis is enclosed in a silk cocoon, mixed with the discarded hairs of the caterpillar. It normally overwinters in the chrysalis state amongst rubbish, dead leaves, or in any situation which affords slight protection. On apple the chrysalis is frequently attached to a curled leaf.

The Buff Ermine Moth is not regarded as being important on apple, but it is a further addition to the long list of insects recorded as feeding on this host.

7. Muslin Moth (*Cycnia mendica* Clerck).

The Muslin Moth, a species closely allied to the Buff Ermine Moth, is another species which is a novelty on fruit. The caterpillars of this moth have been noted commonly on apple and plum in widely separated orchards around the Maidstone district.

The caterpillar is characteristic of the species in the family. It is short and stout. Head round, shiny light brown ; body dull greyish brown, with tubercular spots paler brown ringed with grey ; hairs short and soft, extremely dense, golden brown ; spiracles pale, ringed with black ; beneath them is a row of white dots ; legs and prolegs yellowish brown. This description of the larva has been adapted from Barrett's work.

The normal host plants of the caterpillar are nettle, dock, chickweed, and many other weeds. The insect overwinters in the chrysalis state in a cocoon made of silk and mixed with the larval hairs. The moth is on the wing in May and June and the species is widely distributed in the British Isles.

8. Apple Sawfly (*Hoplocampa testudinea* Klug).

It is well known that many common fruit insects vary in numbers from season to season. In a given year, for example, they may be sufficiently abundant to cause much harm, unless measures are taken to eradicate them, while in others they may be relatively uncommon and control measures are unnecessary. A clear-cut example of this kind of fluctuation has been seen in the behaviour of the Apple Sawfly which has been very scarce in many commercial apple orchards in the Maidstone district. Populations have been unusually low in the Rochester district and in North Kent. Apple Sawfly was more prevalent round Canterbury, but in this locality the populations were below normal. Many factors account for fluctuations of insect populations, such as climate, predators and parasites, cultural methods, insecticides, etc. In this instance it is likely that benzene hexachloride may be largely responsible for the reduced sawfly populations. BHC is very effective against sawfly if the application is timed correctly and used at the proper strength.

In many apple orchards the sawfly population was so low that the routine wash was omitted, and it may be some years before further applications are necessary.

9. Pear Sawfly (*Hoplocampa brevis* Klug).

The pear plantations at Hoo, near Rochester, Kent, where the outbreaks of Pear Sawfly were discovered three years ago, were visited several times during and after the blossom period, but no trace of the insect could be found. A further visit was made later in the season, and a final check made to discover damaged fruits, if any, but none were seen. It would seem, therefore, that the original outbreak has been eradicated. The sprays used were parathion and benzene hexachloride.

10. Common Gooseberry Sawfly (*Pteronidea ribesii* Scop.).

The Common Gooseberry Sawfly was more plentiful than for several years in commercial gooseberry fields in many parts of Kent. The early attacks were noted at the end of April and early in May. The sawfly does not seem to show any varietal preference and in one field the infestation was similar on six varieties.

Gooseberry growers are reminded that it well repays to examine their bushes during the last week of April to see whether the first generation of larvae are present. It is not generally realized that three generations occur each year, and the infestation gradually builds up as the season advances, that is, if the first generation is not checked by spraying with DDT or a similar insecticide directly it is discovered.

11. Apple Capsid (*Plesiocoris rugicollis* Fall.).

During the past five years outbreaks of Apple Capsid have been negligible in commercial plantations. The decrease of this once very prevalent pest followed the incorporation of DDT into the green cluster lime-sulphur spray.

The Apple Capsid still persists, however, in a few neglected orchards, and those which do not receive regular pre-blossom applications of insecticides. In addition small infestations have been noted in apple orchards at East Malling, East Sutton, and several plantations in West Kent. One severe attack was reported in an orchard in East Sussex where little spraying had been carried out for three seasons. The outbreaks seen in Kent were unusual in that the immature bugs confined their feeding to the foliage, producing the familiar capsid markings, but did not damage the fruitlets. In one orchard at Keston, Kent, the capsid was confined to the variety Laxton's Superb ; other culinary varieties in the same orchard were not attacked.

The known host plants of the capsid in addition to apple are various species of Salix and Bog Myrtle, and, since these wild hosts were not growing near the orchards where the capsid attacks were noted, it remains to be discovered whether there are further wild hosts as yet unknown.

12. Fruit Tree Leaf Hopper (*Typhlocyba froggatti* Baker).

The Fruit Tree Leaf Hopper was very common on apple at the Research Station at the end of May. It was also prevalent on the same fruit in the Maidstone district and occurred in both well cared-for and neglected plantations. This species is recognized as the common species on top fruits, the level of populations varying from season to season. There are two generations in a season, the eggs of the second generation being laid in tissue on the under-surface of the leaf. The insect overwinters in the egg state, the eggs being laid in the young wood and spurs. At present, the fruit tree leaf hoppers have not been regarded as important fruit insects, but their status will have to be reviewed as possible vectors of top fruit virus diseases.

13. Cherry Leaf Hopper (*Cicadella stellulata* Burm.).

The fragile, and very prettily marked Cherry Leaf Hopper was very prevalent in several cherry orchards at East Malling in June. The insects were noted on several varieties, but seemed to be more partial to Early Rivers. Severe leaf mottling occurred at the end of June, giving the foliage the appearance of being affected by the silver-leaf disease.

This leaf hopper also feeds on the foliage of pear and plum, but is always more numerous on cherry.

The Cherry Leaf Hopper was very common in the East Malling district in 1940, but it has not been plentiful again until this year.

14. Red and Black Froghopper (*Cercopis sanguinea* Geoff.).

The Red and Black Froghopper, or ' Cuckoo Spit ' as it is sometimes called, is a very active and conspicuous insect in the adult state. The forewings are chequered with red and black markings, and it is nearly half an inch long. The immature stage is pale yellow, and is completely covered by a frothy secretion or ' spittle '. The natural host plants of this insect are dock and willowherb, and the nymph feeds on the stems and roots of these plants.

The adult froghopper feeds on many plants, including top and soft fruits, and the species was common on apple in June at Keston, Maidstone, Sittingbourne, and Staplehurst. On apple the feeding is confined to the upper sides of the leaves, where large greenish-yellow markings are produced ; later they turn reddish-brown. These markings are angular, and often very numerous, numbering up to two hundred or more on one leaf ; they are equally conspicuous on both surfaces. Similar injury is caused on many other plants. This froghopper infests pear, but, curiously enough, on this host it feeds on the developing fruitlets, and not on the foliage. The feeding produces a very rough skin, with corky patches and small blisters, and when the attack is severe much splitting results. The stalk may be scarred and twisted, producing a malformed fruit. A serious infestation was seen in a pear plantation at Staplehurst, Kent, at the end of June.

15. Pear Sucker (*Psylla pyri* L.).

Infestations of Pear Sucker have been seen in many parts of Kent, and particularly bad attacks have been noted at Cliffe, near Rochester, Dartford, Maidstone, Sittingbourne, and Teynham. This insect has been much more prevalent in the past two seasons, and must be regarded as one of the more serious pear pests.

Several species of Psylla occur on pear, and this has led to considerable confusion. The harmful species is considered by Mr. F. Laing, an authority on this group of insects, to be *Psylla pyri* L.

The Pear Sucker overwinters in the plantation in the adult stage, attached to the spurs, branches, and trunks of the trees. Some seek shelter in dead leaves, hedge bottoms, and in ivy growing on walls and fences around the plantations. The Pear Sucker flies readily during sunny, open spells of winter, and does not appear to be affected by periods of intense cold.

The minute, lemon-yellow eggs are laid on the spurs and shoots from early March until the blossom period, and may continue until petal-fall. Nymphs were first observed on 22nd March, and hatching continued until petal-fall. The pinkish-coloured nymphs collect into masses on the unopened flower trusses and feed on the opening buds. The immature bugs emit sticky secretions on the flower trusses giving the trees a very unsightly appearance. Three generations were noted in the field this year, but the number may vary in a more normal season. The adult suckers become more numerous as the season advances, and by the time of the third generation they are very plentiful, and the sticky secretions deposited on the foliage and young growths very much more conspicuous. A sooty black mould, *Cladosporium herbarum* Fr. (Link ex Fr.), grows on this sticky secretion, causing the foliage, shoots, and fruits to blacken. The sooty black mould grows on the fruitlets, and, in the case of heavy infestations, each fruit has to be washed or cleaned prior to being put in store or sent to market.

Ants, wasps, and several species of Diptera are attracted to the honeydew, and the presence of these insects can act as a warning to the grower that Pear Sucker is prevalent in his plantation.

Pear Sucker is partial to many varieties, including Conference, Laxton's Superb, Fertility, and Williams'. Dr. Jules Guyot does not appear to be very susceptible.

Detailed experiments on the control of this pest have not been undertaken, but nicotine appears to be very effective against both the adult and egg. The application should be made at the white bud stage, at a strength of 5 oz. nicotine (95-98 per cent) to 100 gallons of water ; a fungicide can be added if necessary. It should be noted that neither BHC nor DDT is effective against this insect.

16. Cherry Beetle Mite (*Sphaerozetes lapidarius* Mic.).

Some years ago the Cherry Beetle Mite was invariably found in commercial cherry, apple, and plum plantations, but it largely disappeared when applications of tar washes were applied each winter. It is notable that the Cherry Beetle Mite is still plentiful to-day in unsprayed orchards. The species hibernates in the adult state in cracks and crevices of the bark and in large colonies attached to sheltered positions of buds and spurs. Its food consists chiefly of moss, lichen, and other foreign growths of the trees.

Enquiries concerning this mite were numerous and came from cherry growers at East Malling, Canterbury, and the Maidstone district. In each case the mites were reported to be causing considerable harm by feeding on the ripening cherries. They always select fruit that is beginning to crack, and their feeding quickly renders it useless. It is an example of an otherwise beneficial animal occasionally causing harm. The injury was noted during the first and second weeks of June, and in one orchard at East Malling the mites were so numerous that the crop was not gathered from a number of trees.

The very high mite populations in the cherry orchards at East Malling cannot be explained, and the fact that the trees received a routine winter wash in December, suggests that the populations must have been very small in the early spring and built up rapidly later on.

17. Dipterous egg masses on apple shoots.

For a number of years minute, black egg masses, which had not been determined, have been found on both surfaces of leaves and attached to the stems of apple rootstocks at the Research Station. These eggs are usually deposited in a regular pattern, or sometimes indiscriminately, on one shoot each of a number of apple stools. The eggs are laid about the middle of June, and the minute larvae hatch out towards the end of the month. This year these egg masses were also noted on the leaves of some young apple trees at Gillingham. They belong to a species of Diptera of the family *Acroceridae* (*Cyrtidae*) and are probably contained in the genus *Oncodes*.

The larvae are parasitic on spiders, and this possibly explains why it has not been possible to rear them. The first stage larva is very active, using the bristles near the top of the abdomen to make progress by a leaping movement. It is a coincidence that this insect deposits its egg masses occasionally on the leaves and stems of apple. It is not harmful to the plant. The writer is indebted to Mr. H. Oldroyd for identifying this fly and for other information concerning it.

18. Beneficial insects.

Observations have been made during the past two seasons of certain beneficial insects occurring in a number of adjacent apple orchards extending over one hundred acres. These orchards are isolated and are partly surrounded by woods and coppices. In addition, the orchards have not been sprayed with a winter wash for two seasons and the summer insecticides have been reduced to a minimum ; DDT, BHC, and parathion have not been used during this period. A survey of the orchards in August, 1950, showed that the species of beneficial insects were few and their populations low in all orchards.

One result of the modified spray programme has been the gradual return of beneficial insects to the orchards. By the autumn of 1951 a few Black-kneed Capsids had established themselves, and two species of Anthocorid bugs were present on some trees. One year later many more species were present, and some in considerable numbers. The more important were as follows :—the Black-kneed Capsid (*Blepharidopterus angulatus* Fall.), three species of *Anthocorids*, two species of *Orius*, *Atractotomus mali* (M.-D.), *Psallus ambiguus* (Fall.), *Himacerus lativentris* (Bok.), and the minute black Ladybird (*Stethorus punctillum* Weise.).

It is encouraging to find so many beneficial insects returning to these orchards after a relatively short period, some of them building up large populations. It should be noted that all the species are predaceous on the Fruit Tree Red Spider Mite, on which they are feeding actively, and that a red spider problem exists in the orchards.

19. Apple Whitefly (*Aleyrodes fragariae* Walk.).

A species of whitefly has been noted breeding on apple for a number of years but it has not been sufficiently common to cause any injury to the trees. It is usually more common on apple rootstocks and on young seedling apples than on established trees. The scale of the immature forms feed on the undersides of the foliage. The Apple Whitefly was more prevalent at East Malling this summer than usual, and was also common on some young apples at Shepherdswell, Kent, in July. The writer is indebted to Mr. F. Laing for the determination of this species as *Aleyrodes fragariae* Walker (=*A. lonicerae* Walker).

Summary.

Short notes are given on some of the interesting insects and mites noted on fruit in 1952. Among those mentioned are the Flax Flea Beetle, the Apple and Plum Case Bearer, the Buff Ermine Moth, the Muslin Moth, the Red and Black Froghopper, the Pear Sucker, the Cherry Beetle Mite, and the Apple Whitefly.

STUDIES ON CONTROL OF APPLE SAWFLY, *HOPLOCAMPA TESTUDINEA* (KLUG)

I. EFFECT OF TIME OF SPRAYING

By G. H. L. DICKER and J. B. BRIGGS

The occasional failure of nicotine to give satisfactory control of the Apple Sawfly, *Hoplocampa testudinea* (Klug), led to a renewed study of this problem in the immediate post-war years. In this country Davies and Eaton (1950), followed by Kirby and Gambrill (1953), tested a number of recently discovered insecticides, obtaining consistently good results with γ-BHC, parathion, and chlordane, whilst aldrin, dieldrin, and toxaphene were also very effective in a single trial. Biological studies by Dicker (1953) indicated that oviposition occurred only in open blossoms, there being no evidence that past failures could be due to egg laying after the petals had fallen and the spray had been applied.

It is now known that very similar work was in progress by Kuenen and van de Vrie (1949, 1951) in the Netherlands. These workers, in addition to biological studies, carried out an extensive series of field trials to assess the insecticidal action of γ-BHC, rotenone, and parathion, when applied at different stages in relation to the hatching of the eggs.

The present investigation, complementary to the work of Davies and Eaton, and Kirby and Gambrill, was undertaken to discover whether the more promising of the newer insecticides suffered from the same limitations as nicotine, and to find, if possible, an explanation for the occasional failure of the latter. To this end trials were laid down in which sprays were applied at the 80 per cent petal fall stage and at intervals during the following fortnight, this being considered the maximum period in which satisfactory control would be possible without undue injury to the crop.

Materials and methods.

Commercial formulations of parathion and BHC were used, the former as a 20 per cent dispersible liquid, the latter as a 50 per cent wettable powder ; the nicotine was of 95-98 per cent purity. Sodium dioctyl sulphosuccinate at 0·0125 per cent was added as wetter to all sprays containing nicotine and to the lower concentration of parathion used in 1949. A fungicide, 1 per cent lime-sulphur in 1949 and 0·4 per cent dispersible sulphur in 1950 and 1951, was added to each insecticidal spray, the controls being sprayed with the fungicide alone when the earliest application was made.

The trials were carried out on a plot in which three rows of Cox's Orange Pippin alternated with one row of Worcester Pearmain. Both varieties were worked on M.IX rootstocks, planted in 1935-6, and grown as bush trees. A randomized block lay-out with single tree plots was used, there being eight replicates in 1949 and six in subsequent years. Sprays were applied by hand lance at about 250 lb. per sq. in., each tree receiving from three-quarters to one gallon of wash. When necessary a canvas screen was used to shield other treated trees from drift.

All dropped fruits were collected from beneath each tree at twice-weekly intervals and examined for sawfly injury. Collections began during the first half of June and continued until the latter half of July, by which time all attacked fruits had fallen ; the fruits remaining on the trees were then counted. The earliest collections contained fruits with a minimum diameter of 4-5 mm., those with reflexed sepals being rejected.

Damaged fruits were assigned to one of three grades : *primary*, in which the larva, after initial peripheral tunnelling, bored into the centre of the fruit ; *secondary*, with a direct radial entry to the core, and *scarred*, in which the progress of the larva had been arrested, usually as a result of insecticidal action, whilst the peripheral tunnelling was in progress. The figures quoted for infestation are obtained by expressing the number of fruits in the primary and secondary categories as a percentage of the total remaining on the tree after the unfertilized blossoms had been shed.

For statistical analysis all data were transformed to angles of equal information ; these figures are included in the tables in addition to the arithmetic means.

Throughout this paper the term petal fall is synonymous with the 80 per cent petal fall stage as defined by Hey and Steer (1934), i.e. ' when about 80 per cent of the petals have fallen and when most of the remainder fall readily when the tree is shaken lightly '.

1949 Trial.

Carried out on trees of the variety Worcester Pearmain, this trial was designed to compare the effect of two concentrations of parathion applied at five different dates (Table I). The first spray was applied on 13th May, at 80 per cent petal fall, and subsequent ones at intervals during the next fourteen days. Hatching of sawfly eggs began during the period 14th-17th May, reached 50 per cent on 22nd May, and was completed by 28th May.

TABLE I.

MEAN PERCENTAGE INFESTED FRUIT, WORCESTER PEARMAIN, 1949.

Treatment.	Date of application.									
	13th May.		17th May.		20th May.		23rd May.		27th May.	
		*		*		*		*		*
0·0025% parathion	**0·5**	3·7	**2·9**	9·2	**0·6**	4·4	**0·6**	4·0	**1·2**	5·6
0·01% parathion ..	**0·1**	2·1	**0·8**	4·4	**0·1**	2·0	**0·02**	1·7	**0·1**	2·1
Control	**14·8**	22·0	—	—	—	—	—	—	—	—

* Data transformed to angles of equal information. *Sig. diff.* ($P=0·05$)=2·52 *for* 0·0025% *parathion and* 1·60 *for* 0·01% *parathion.*

All treatments gave significant reductions in infestation compared with the controls ; in addition, 0·01 per cent was significantly more effective at each date of application than 0·0025 per cent. Within each concentration the application on 17th May was significantly less effective than sprays applied on other dates which did not differ significantly among themselves. The relatively poor control achieved on 17th May was undoubtedly due to inefficient spraying resulting from unfavourable weather conditions ; a fairly strong wind was blowing and, in an endeavour to prevent drift from contaminating neighbouring trees, a thorough cover was not obtained.

Viewed as a whole the results show that, with good spraying, 0·01 per cent gave 99 per cent control of the Apple Sawfly when applied at any time during the fortnight immediately following 80 per cent petal fall. Over the same period 0·0025 per cent gave control of about 96 per cent with an indication that efficiency was falling off at the last application.

1950 Trial.

Adjacent rows of Cox's Orange Pippin and Worcester Pearmain were used, the plot lay-out being identical for each variety except where unsuitable trees occurred. With few exceptions each replicate thus contained two neighbouring trees, one of each variety. As a compromise between the strengths used in 1949 a relatively low concentration, 0·005 per cent parathion, was chosen and, in view of the effect of parathion on the June drop, noted in 1949 and to be discussed in a subsequent paper, a further treatment of 0·005 per cent parathion plus 10 p.p.m. α-naphthaleneacetic acid (NAA) was included ; 0·05 per cent nicotine completed the treatments (Table II).

The first spray was applied on 17th May when Worcester Pearmain was at the 80 per cent petal fall stage, Cox's Orange Pippin having reached this stage about two days previously. Hatching of sawfly eggs began during the period 23rd-25th May, reached 50 per cent on 27th May, and was completed by 2nd June.

TABLE II.

MEAN PERCENTAGE INFESTED FRUIT, WORCESTER PEARMAIN, 1950.

Treatment.	Date of application.							
	17th May.		22nd May.		26th May.		31st May.	
		*		*		*		*
0·005% parathion	**0·8**	4·8	**0·5**	3·8	**0·3**	2·8	**0·4**	3·5
0·005% parathion+10 p.p.m. NAA ..	**0·3**	3·6	**0·2**	3·1	**0·7**	3·9	**1·8**	6·7
0·05% nicotine	**0·8**	4·3	**0·4**	3·1	**0·5**	3·9	**8·2**	15·7
Control	**5·0**	11·7	—	—	—	—	—	—

* Data transformed to angles of equal information. *Sig. diff.* ($P=0·05$)=3·47.

A very poor set of blossom on Cox's Orange Pippin, probably due to lack of pollination, resulted in too few infested fruits for any definite conclusions to be drawn regarding the efficacy of the various treatments.

The infestation on Worcester Pearmain, though low, did show a significant reduction in infestation over the control by all treatments except the last nicotine spray. In addition, parathion applied on 26th May and parathion plus NAA and nicotine applied on 22nd May were just significantly better than parathion plus NAA applied on 31st May which did not differ significantly from the remaining treatments.

Control with 0·005 per cent parathion, although not quite as good as obtained in 1949 with a still lower concentration, was of the order of 90 per cent for all applications except the last with parathion plus NAA. Nicotine gave similar control up to ten days after petal fall but beyond this period it failed completely.

1951 Trial.

The lay-out was the same as in 1950, i.e. each replicate contained two trees, one of each variety, from adjacent rows of Cox's Orange Pippin and Worcester Pearmain. The concentration of parathion was increased to 0·0075 per cent, 0·006 per cent γ-BHC was brought in to replace parathion plus NAA, and nicotine retained (Table III). The first spray was applied on 26th May when Cox's Orange Pippin was approaching the 80 per cent petal fall stage, Worcester Pearmain having reached it on the preceding day. Hatching of sawfly eggs began during the period 26th-29th May, reached 50 per cent on the 5th June, and was completed by 9th June.

With minor variations the results are similar for both varieties. Although giving highly significant reductions compared with the controls there is no significant difference between the times of application for either parathion or BHC, nor, with the exception that the first parathion spray is significantly better than the last BHC on Worcester Pearmain, is there any significant difference between these treatments. The nicotine sprays applied to Worcester Pearmain on 26th May and 9th June were significantly less effective than all other sprays applied to this variety, the resulting infestations not differing significantly from that on the control. Similar sprays applied on 1st and 5th June gave

TABLE III.

MEAN PERCENTAGE INFESTED FRUIT, WORCESTER PEARMAIN AND COX'S ORANGE PIPPIN, 1951.

Treatment.	Date of application.							
	26th May.		1st June.		5th June.		9th June.	
Worcester.		*		*		*		*
0·0075% parathion	**0·0**	1·4	**0·3**	2·8	**0·2**	2·4	**0·1**	2·0
0·006% γ-BHC	**0·1**	1·8	**0·3**	2·7	**0·2**	2·2	**0·8**	4·3
0·05% nicotine	**3·2**	9·7	**0·8**	4·7	**0·7**	4·1	**4·0**	9·6
Control	**4·8**	12·2	—	—	—	—	—	—
Cox.								
0·0075% parathion	**0·1**	2·2	**0·1**	1·9	**0·2**	2·4	**0·2**	2·5
0·006% γ-BHC	**0·2**	2·4	**0·2**	2·7	**0·03**	1·8	**0·8**	4·7
0·05% nicotine	**3·1**	9·4	**1·3**	5·9	**0·9**	4·7	**4·9**	11·6
Control	**7·9**	14·3	—	—	—	—	—	—

* Data transformed to angles of equal information. *Sig. diff.* ($P=0·05$) $=2·76$ *for Worcester and* $3·90$ *for Cox.*

significant reductions, but the former was still significantly less effective than parathion or BHC applied on 26th May. When applied to Cox's Orange Pippin on 9th June, nicotine did not reduce the infestation significantly ; the application on 26th May gave significant control but was still significantly inferior to all other treatments except nicotine applied on 1st June. Applications on 1st and 5th June also reduced the infestation significantly, although the former was significantly less effective than parathion applied on the same date and BHC applied on 5th June.

In more general terms parathion gave uniformly good control, varying from 94 to 100 per cent reduction in infestation, throughout the period of spray applications ; BHC was equally effective up to 5th June but showed a marked though barely significant drop in efficiency when applied to both varieties on 9th June. The first and last applications of nicotine were virtually ineffective ; the intermediate ones gave control of the same order as the last application of BHC, achieving a reduction of 83-89 per cent.

Discussion of results.

Over the three-year period covered by this investigation parathion has given consistently good results. When applied at 0·01 per cent in 1949 and 0·0075 per cent in 1951 the reduction in infestation exceeded 94 per cent irrespective of the date of application, which varied from 80 per cent petal fall to a fortnight later, there being no indication that reduction in efficiency of the spray occurred at any time during this period. In 1949, with the exception of the low kill on 17th May, 0·0025 per cent parathion gave control of 92 per cent or higher during the same period with a suggestion that efficiency was falling off at the final application. Similarly in 1950, although the degree of control was generally rather lower, consistent results were obtained with 0·005 per cent parathion throughout the two-week period following petal fall, but when this same concentration was applied with NAA, the last spray, on 31st May, gave significantly inferior control. There is thus an indication that the lower concentrations are liable to be less effective when applied more than ten days after 80 per cent petal fall. Small trees were used in the above experiments and the control achieved with the lower concentrations is greater than that obtained with comparable strengths by Kirby and Gambrill (1953), whose experiment was conducted under conditions approaching more closely to those present on the commercial fruit farm. However, provided the spray is applied efficiently, there seems no reason why excellent control of the Apple Sawfly should not be obtained under normal commercial conditions without exceeding a concentration of 0·0075 per cent parathion. The significantly lower control obtained with 0·01 and 0·0025 per cent on 17th May, 1949 (Table I) serves to underline the importance of efficient spraying and demonstrates how, with this pest in particular where the spray has to cover each fruitlet to be effective, only a slight reduction in the high standard required can have a markedly adverse effect on the result.

Although included only in the 1951 trial, 0·006 per cent γ-BHC gave control of the same order as 0·0075 per cent parathion during the ten-day period immediately following 80 per cent petal fall ; when applied fourteen days after petal fall there was a marked, though not significant, drop in performance on both Worcester Pearmain and Cox's Orange Pippin.

0·05 per cent nicotine gave best results when applied at approximately five and ten days after 80 per cent petal fall ; on these occasions being as effective as 0·005 per cent parathion in 1950, but in 1951 showing a marked, though not generally significant, inferiority to both 0·0075 per cent parathion and 0·006 per cent γ-BHC. Good control was obtained with the petal fall application in 1950 but not in 1951 ; in both years nicotine failed to give effective control at fourteen days after petal fall. Possible causes of failures have been discussed by Kirby and McKinlay (1953), who confirmed the observations of Kearns, Marsh, and Martin (1936) that nicotine does not act as an ovicide, and postulated that, for sprays applied prior to hatching, nicotine may be bound as a salt of one or more organic acids to form a persistent insecticide acting as a stomach poison against the young larva. These workers also brought together evidence to discount the long established theory that successful control was dependent on a fairly high temperature at the time of spraying. Instead, they suggested that the persistence of the salt may be of short duration and poor control, following a petal fall spray, could result from delayed hatching due to unfavourable climatic conditions ; alternatively, calyx closure before the application of a later spray may prevent the insecticide penetrating into the calyx. The latter explanation, coupled with the reduced activity of nicotine compared with parathion or BHC observed against tunnelling larvae, would explain the failures in 1950 and 1951 when this spray was applied fourteen days after petal fall. The persistence theory alone, however, is of doubtful value in accounting for the low control obtained by spraying on 26th May, 1951. The period from spraying to 50 per cent hatch was ten days whereas in 1950, and in three trials mentioned by Kirby and Gambrill, satisfactory control was achieved with an interval of nine days. These authors discounted the leaching action of rain which may have been important in 1951, when 0·29 in. fell within twenty-four hours of spraying.

All three insecticides were applied with a fungicide, 1 per cent lime-sulphur in 1949 and 0·4 per cent dispersible sulphur in 1950 and 1951. From the high degree of control obtained with parathion and BHC there is no reason to suspect that any reduction in toxicity was caused by the addition of either form of sulphur. As far as the writers are aware, no detailed comparisons have yet been made between sprays containing nicotine alone and combined with a fungicide, but a study of many individual trials reported by previous workers gives no indication that the addition of sulphur would be detrimental.

Considered in relation to the biological data all concentrations of parathion and 0·006 per cent γ-BHC gave consistent results when applied at various dates between 80 per cent petal fall, i.e. about four days before eggs began to hatch, and the time when 50 per cent of the eggs had hatched. Only one further application was made, approximately when hatching was complete, and at this stage there was evidence that parathion below 0·0075 per cent and 0·006 per cent γ-BHC were slightly less effective. Kirby and McKinlay (1953) have demonstrated that these materials have no ovicidal

effect but kill the young larvae on emergence from the eggs by contact action. Reduction in effectiveness of the later sprays would, therefore, most probably be due to their failure to reach the tunnelling larva.

Fruits in which the young larvae have been killed whilst tunnelling beneath the epidermis can be recognized by a superficial scar, at the distal end of which the dead insect can be found if examination takes place before subsequent growth of the fruit has caused the damaged epidermal tissue to crack and shrivel. Such fruits were recorded separately and it was found that, with rare exceptions, none occurred on trees receiving sprays less than ten days after 80 per cent petal fall ; a few occurred following most treatments applied at this time and a relatively large increase was observed from the last spray applied four days later. This shows that very few larvae had penetrated beyond the calyx by the tenth day after petal fall, but after this date the number increased rapidly. Death of tunnelling larvae is due to penetration of the epidermis by the insecticide and, from the records, it would appear that, in this respect, parathion is slightly more effective than BHC, whilst both these materials killed about twice as many larvae as nicotine. It is clear, therefore, that nicotine is not very effective against tunnelling larvae and this offers a partial explanation for the failure to obtain control with late applications of this insecticide.

In the present trials practically all scarred fruits fell before the end of July, but Hey and Steer (1934) record considerable numbers remaining on the trees until maturity. To avoid possible losses due to blemished fruits it would thus be inadvisable to delay spraying later than ten days after petal fall.

Effect on yield.

Very marked increases in crop followed the use of parathion in 1949 and 1951 ; this will be discussed more fully in a later paper.

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Summary.

In field trials carried out during 1949-51 infestations of Apple Sawfly, *Hoplocampa testudinea* (Klug), were reduced by 94-100 per cent following the use of 0·0075 or 0·01 per cent parathion at various dates during the two-week period immediately after 80 per cent petal fall, i.e. from about four days prior to the hatching of the first egg to full hatch. 0·0025 and 0·005 per cent parathion and 0·006 per cent γ-BHC gave satisfactory control up to ten days after petal fall, i.e. to 50 per cent egg-hatch, but were less effective at full hatch. 0·05 per cent nicotine gave variable results when applied at petal fall, was most effective five or ten days later, and ineffective at full hatch. Possible causes for the failure of nicotine are discussed.

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PRELIMINARY TRIALS FOR THE CHEMICAL CONTROL OF THE SUMMER FRUIT TORTRICID

By JOAN R. GROVES and R. P. TEW

Following the discovery of the Summer Fruit Tortricid, *Adoxophyes orana* (F.R.)=*Capua reticulana* (Hb.) (Groves, 1952) causing damage to apples in South-East England, it has been necessary to undertake some experimental work on its control, the object during the first season being to test the efficiency of some insecticides already in general use.

Recently workers in Holland (de Jong, 1951) have demonstrated the susceptibility, particularly of early instar larvae and of the adult moth, to a number of established insecticides and have obtained promising results with parathion and DDT in the field. It was therefore logical that these insecticides should form the basis of our first experiments at East Malling.

Two trials were undertaken : (i) a *winter-spring* (delayed dormant-green cluster) trial directed against overwintering larvae, either still in hibernation or after moving to opening foliage, and (ii) a *summer* trial directed against moths and larvae of the summer generation.

Winter-spring trial.

The trial plot consisted of a double row of apple trees, with the varieties Beauty of Bath and James Grieve planted alternately in each row. The Beauty of Bath were used as single tree plots and the James Grieve as unsprayed guard trees. Each treatment was replicated seven times.

On the first occasion (delayed dormant stage) there were three treatments ; these were subdivided on the second occasion (green cluster stage) into six treatments as shown in Table I.

TABLE I.

WINTER-SPRING TRIAL—TREATMENTS AND AVERAGE NUMBER OF LARVAE OF OVERWINTERING GENERATION OF SUMMER FRUIT TORTRICID IN 200 TRUSSES PER TREE IN MAY, 1952.

Treatment No.	At delayed dormant stage (applied 11th March).	At green cluster stage (applied 16th April).	Average No. of larvae.
1	Unsprayed	Unsprayed	10·9
2		DDT 0·1%	1·9
3	DNC 0·1% Petroleum 4%	Unsprayed	1·4
4		DDT 0·1%	0·3
5	DNC 0·1% Petroleum 4% DDT 0·1%	Unsprayed	0·4
6		DDT 0·1%	0·6

Note.—All percentages refer to active ingredient.

Commercial formulations of DNC/petroleum, complying with clauses 1 and 5 of the Ministry of Agriculture Specification (1951b), and of DDT, 20 per cent wettable powder, were used. Both products were included in the Ministry of Agriculture Crop Protection Products Approval Scheme (1951a) and the content of active ingredient was checked by chemical analysis.

Observations showed that the larvae emerged from their overwintering cocoons during the first three days of April. Results were assessed on 9th and 10th May, just after petal fall, by the method described by Dicker and Briggs (1952) except that only 200 trusses (50 from each side) were inspected from each tree.

The number of larvae on trees under all treatments differ significantly ($P=0·001$) from the number on the controls but do not differ significantly ($P=0·05$) from each other. There is, however, an indication that neither DNC/petroleum alone nor DDT at green cluster only are as effective as both materials applied together or in succession. Even the complete programme did not give adequate

control and, in all probability, would not have prevented damage to the fruit, as the small residual population could have built up to a high level again during the summer generation.

Summer trial.

The orchard consisted of half-standard apple trees of Beauty of Bath. The toxicants selected for this trial were DDT and parathion, in view of promising results in Holland, and toxaphene, because a build-up of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), is less likely after its use than after a summer spray of DDT. The six treatments shown in Table II were replicated six times in randomized blocks.

TABLE II.

SUMMER TRIAL—TREATMENTS AND PERCENTAGE CROP DAMAGED BY LARVAE OF THE SUMMER GENERATION OF THE SUMMER FRUIT TORTRICID.

Toxicant.	Percentage concentration of active ingredient.	Date(s) of application.	Percentage crop damaged.
None	—	—	19·6
Parathion	0·01	5th June	17·3
Toxaphene	0·15	5th June	12·0
Toxaphene	0·15	5th June and 23rd June	9·9
DDT .. .. .. Parathion	0·1 0·01	5th June	8·6
Parathion	0·01	5th June and 23rd June	6·7

In the last column values within the brackets on the right do not differ significantly (P=0·001). Values within the brackets on the left do not differ significantly at the 0·05 level.

The sprays were applied on the dates shown in Table II. As in the earlier trial they were prepared from commercial materials ; the DDT wettable powder was drawn from the same batch as that used in the earlier trial, the parathion and toxaphene sprays were prepared from emulsifiable concentrates containing toxicant, solvent, and surfactant. Daily records at East Malling showed that the first flight of moths began on 27th May and continued until 20th June. Eggs are normally laid a few days after emergence and hatch in 10-14 days. It was not possible to take such detailed records on the farm where the trial took place, but observations showed that the flight period was about the same.

Both picked fruit and drops from each treated tree were examined and the percentage total crop showing damage by the full-grown larvae of the summer generation calculated. The crop was picked over twice (21st and 28th July) and the trees cleared at a third picking on 1st August.

The results indicate that DDT, parathion, and toxaphene are all effective agents in reducing the damage by the summer brood of the Summer Fruit Tortricid. The single application of parathion gave rather better initial control than the figure indicates, the high infestation on these plots being due to subsequent reinfestation by moths from unsprayed guard trees. The more pronounced residual effect of DDT is, no doubt, responsible for the better performance of the parathion/DDT mixture.

The Fruit Tree Red Spider Mite infestation was very low over the whole orchard and did not build up even on the plots where DDT was used. No phytotoxic effect was noticed on the trial plot.

The results of these trials are, in the main, in agreement with the results obtained in Holland and, while suggesting interim measures which may be used, demonstrate the need for further investigation. The first spray was undoubtedly applied too early, and further trials should be made to find the optimum time of application in relation to the stages of the pest present on the tree.

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Summary.

Two trials, one at delayed dormant and green cluster stages, and the other during June, were carried out in commercial orchards to examine the effects of certain insecticides, alone or in combination, against the Summer Fruit Tortricid, *Adoxophyes orana* (F.R.). The results suggest that a considerable measure of control may be secured by an application of DNC (0·1 per cent)/petroleum (4 per cent) and/or DDT (0·1 per cent), in a winter-spring spray schedule, followed by applications of parathion (0·01 per cent) (twice), DDT (0·1 per cent), or toxaphene (0·15 per cent) (twice) in the summer.

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THE GREENHOUSE RED SPIDER MITE, *TETRANYCHUS URTICAE* KOCH, ON APPLES IN EAST ANGLIA

By ELSIE COLLYER

The Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), is the only species of the Tetranychid mites of economic importance on apple in England, although in other parts of the world other members of this family cause serious damage in orchards. During the last few years another mite has appeared in gradually increasing numbers in certain orchards in Essex. Much confusion exists concerning the species of *Tetranychus* and until this genus has undergone a thorough revision it is difficult to decide the true status of the various species. The mite under discussion is the Greenhouse Red Spider Mite, *Tetranychus urticae* Koch ; this species is identical with *T. bimaculatus* Harvey, the Two-spotted Mite of North America. In England it is common on many greenhouse plants, on black currant, and hop ; strawberry is also attacked by this mite or a very closely allied species. The Greenhouse Red Spider Mite has often been called *Tetranychus telarius* L., but this name is now restricted to the mite found on lime (*Tilia*).

In Australia an increase of *T. telarius* has been reported in orchards following the use of DDT (Wason, 1946), and in North America *T. bimaculatus* and other *Tetranychus* species have increased following the use of this insecticide (Chapman, 1947 ; Dean, 1946). DDT is used in these countries during the summer months to control Codling Moth, a practice not followed in England. There is no doubt that *Tetranychus* species are becoming of greater economic importance with the extensive use of the newer insecticides.

Occurrence in Essex.

This mite was first noted in abundance on apple and pear at Hatfield Peverel in Essex, during August and September, 1949, in an orchard where parathion had been applied twice against a serious infestation of the Fruit Tree Red Spider Mite. Earlier in the summer heavy infestations had occurred on hedgerow plants and on weeds growing close to the trunks of the trees in an otherwise clean-cultivated orchard. In the same orchard during 1950-52, three, four, and four or five applications respectively of parathion were used against the Fruit Tree Red Spider Mite, followed by a progressive annual increase in numbers of the Greenhouse Red Spider Mite.

Mites are to be found on hedgerow plants and weeds beneath the trees until July, when movement to apples becomes noticeable. Premature defoliation of the apple trees follows, due to the combined activities of *M. ulmi* and *T. urticae*. In another orchard, at Great Braxted, *T. urticae* was found for the first time in 1952, infesting apple trees from August onwards, this being the second year that parathion had been used as an acaricide. Other cases in Essex have been noted where this mite has appeared following the use of parathion in June and July. Observations show that the mite occurs in small numbers in hedges on many farms, but so far it has been found invading top fruit only where parathion has been used. It has been found in orchards of apple, plum, pear, cherry, and walnut.

Although the Fruit Tree Red Spider Mite occurs naturally in small numbers on unsprayed apple trees, in addition to several other species of Tetranychids, *T. urticae* has not yet been found under such conditions. The Fruit Tree Red Spider Mite increases in sprayed orchards as a result of the adverse effect of many sprays on its predatory enemies. In the same way sprays may be killing off the predators of *T. urticae* in the hedgerows, thereby leading to an increase in the number of these mites in such situations and their subsequent spread to neighbouring fruit trees.

Host plants.

As there is some uncertainty concerning the identity of the species of mite which infests various plants, the *T. urticae* host complex is considered here only in relation to the infestations which have been observed in orchards. In the hedgerow the most favoured host plant is elm (*Ulmus campestris* L.), which is rapidly bronzed and defoliated ; it also lives on many others, e.g. sloe (*Prunus spinosa* L.), wild rose (*Rosa canina* L.), blackberry (*Rubus fruticosus* L.), wild hop (*Humulus lupulus* L.), elder (*Sambucus nigra* L.) and spindle (*Euonymus europaeus* L.). It is also to be found on most wild plants growing in and around orchards, particularly bindweed (*Convolvulus arvensis* L.), groundsel

(*Senecio vulgaris* L.), thistle (*Carduus arvensis* Robs.), dock (*Rumex* sp.), pepperwort (*Lepidium campestre* Br.), mallow (*Malva sylvestris* L.), sage (*Salvia pratensis* L.), toadflax (*Linaria vulgaris* Mill.), nipplewort (*Lapsana communis* L.) and wild strawberry (*Fragaria vesca* L.). In addition it spreads rapidly through the garden on hollyhock (*Althaea rosea* Cav.), rose, tomato, etc., and many ornamental shrubs. In fact the host plant range seems to be almost unlimited.

Life history.

The life history of this mite has not been studied in detail in Essex, but from observations it is obvious that its rate of increase is considerably greater than that of the Fruit Tree Red Spider Mite. In 1952, the first females found on apple in mid-May were bred under unheated laboratory conditions and completed seven generations before the development of overwintering females in October. Compared with *M. ulmi* eggs are laid at a greater rate and have a shorter incubation period. The mite is gregarious in habit, forms a considerable amount of webbing, and the leaves which are attacked become bronzed in a very short time. In other countries this mite has proved difficult to control with acaricides, and it has a very high rate of increase and an almost unlimited range of alternate host plants.

Conclusions.

The pattern disclosed in this preliminary note bears a striking resemblance to that followed by the Fruit Tree Red Spider Mite and, in view of the damage caused by mites of the same genus in other parts of the world, the incipient infestations described require close observation, especially in relation to the use of parathion and other insecticides.

Acknowledgment.

Dr. G. O. Evans of the British Museum (Natural History) very kindly examined the mite material, and his opinions have been followed throughout this paper.

Summary.

The Greenhouse Red Spider Mite (*Tetranychus urticae* Koch) has been noticed for the first time in English apple orchards during the past few years, in all cases where parathion has been used as an acaricide. Notes are given on the host plants and a brief outline of the life history under Essex conditions of this potential pest.

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PLANT PROTECTIVE CHEMISTRY

MODIFICATIONS IN THE GLASS-SLIDE SPORE-GERMINATION TEST FOR USE IN FUNGICIDE RESEARCH

By A. H. M. KIRBY and E. L. FRICK

Plant diseases, such as Apple Scab and Pear Scab, which are spread by air-borne and/or water-borne spores, are usually combated by protectant fungicides, that is, by chemicals applied to the outside of the plants *before* the arrival of the spores. The *modus operandi* is essentially the same in the case of seed disinfectants, except that here the period between the arrival of the spores on the seed and the germination of these spores is usually quite long enough to allow of chemicals being applied to the seed *after* contamination, and yet in ample time to prevent germination of the spores. Studies of the relative toxicities or mode of action of such chemicals require a method in which the spore germination is observed, without the complication of mycelial development. It is, therefore, unfortunate that the slide germination method, which has been so widely used and advocated, should have been discarded recently by some workers in favour of a roll-culture method (Manten, Klöpping, and van der Kerk, 1950). These authors found that their roll-culture method, the common agar-plate method, and the gravimetric method employing liquid cultures, gave concordant results with the fungicide, thiram, but that some organisms gave divergent results with the version of the glass-slide method used by them. They ascribed this divergence to the influence of substrate upon the organisms, the spores in the glass-slide tests having an inferior substrate. It must, however, be pointed out that the first three methods all measure the combined effects of the fungitoxicant employed upon the germination of the spores and upon the subsequent development of the mycelium ; they would, therefore, be expected to give different results from a method that estimates only spore germination, and they have, moreover, much less bearing upon the course of events in agricultural practice. In a recent publication, Sijpesteijn and van der Kerk (1952) have demonstrated that the inversion effect observed for thiram by Dimond *et al.* (1941) and Montgomery and Shaw (1943) is limited to the phase of spore germination. It would appear that the slide germination technique, modified as described herein, would be particularly suited to studies of this phenomenon as well as to studies of structure/toxicity relationships bearing upon the inhibition of spore germination, and certainly simpler to operate than the roll-culture technique, which calls for such a high degree of asepsis.

A number of difficulties are inherent in the glass-slide technique as developed by Montgomery and Moore (1938), including the method of applying the toxicant. Although methods employing horizontal spraying (Horsfall *et al.*, 1940) and settling towers (McCallan and Wilcoxon, 1940) have been advocated, there is no evidence that the earlier method is less accurate. Wilcoxon and McCallan (1939) remark that it is impossible to spray two slides alike, whether time of spraying or concentration of fungicide be kept constant. The use of an elaborate settling tower may overcome some of these difficulties, but it would have to afford a great increase in precision if it were to be considered as an improvement on simple pipetting of the preparation to be studied. The latter procedure, adopted by Montgomery and Moore (1938), has been followed by several workers (Peterson, 1941 ; Young, 1944 ; Miller, 1949), but in cases requiring much organic solvent for formulation, it has been difficult to confine a drop of constant size on a reproducible area while ensuring rapid and complete spreading over that area. Investigations have been carried out during the last two years with a view to solving this and other problems involved in the method of Montgomery and Moore (1938), and the results are described below under six headings. Indications are given in the appropriate sections of the changes made by Montgomery and other workers at this Station during the intervening years, 1938 to 1950.

It should be emphasized that our aim has been to provide as reliable a method of assay as possible for accurate work with spores of *Venturia* spp., and it does not follow that our method is applicable to spores of other fungi, or desirable where information of less accuracy is required.

Stages investigated.

Provision of circular areas.

The slides made by Montgomery and Moore were still in use in 1950, but needing replacement, and consideration was given to the best method of making new ones. The use of a wax circle, drawn with a wax-pencil (Miller, 1949), or the more standard paraffin-wax circle applied mechanically (Zobrist,

1952), could doubtless serve well for screening purposes, but is hardly desirable for accurate work, especially where organic solvents may be present. As glass remains the only material which is transparent, rigid, and unattacked by chemicals likely to be employed in such tests, the problem is how to delimit areas of glass.

Cavity slides can be used (Barrett and Horsfall, 1947 ; Manten *et al.*, 1950) but must have a flat bottom to the cavity which will in any case be difficult to clean thoroughly ; few, if any, such slides on the market have more than one cavity. A new method employing microbeakers has recently been reported by Shafer (1952) ; it seems likely that the difficulty of obtaining a flat bottom will apply here also. Moreover, this author's recommendation to remove one or two drops to a slide for the counting stage seems to ignore the tendency for germinated, rather than ungerminated, spores to adhere to the bottom of the beaker, and this procedure would give an unrepresentative sample. The procedure of Peterson (1941), who attached circular cover-slips to slides by a film of petrolatum, leads to a raised area but, in our experience, the edges of such circles are quite unsuitable, being curved. The need, when solutions or suspensions containing much organic solvent or an efficient wetting agent are being used, is for an area limited all round by a sharp fall, i.e. an edge as near 90° as possible and having no channelling anywhere. Montgomery and Moore (1938) used a diamond-pencil and made a circular scratch, using a lathe to guide the tool, but the groove was shallow and the edge uneven. Young (1944) employed hydrofluoric acid in grooves cut in paraffin wax with which he had coated slides ; here again the groove is apt to be shallow and the edge will be only as smooth as the groove in the paraffin, which calls for a special technique. The alternative is to drill the glass with a suitable tool : either a diamond-impregnated drill, as is used for cutting holes in glass plate, or a copper drill using fine carborundum and water. The latter drill gives a circle with an excellent edge, but will only make a few circles and then has to be remade. The former drill is apt to give circles with small chips however many precautions are taken, but by drilling a deep groove, then planing away the surface of the slide until the chipped zone has gone, and finally polishing clean, a very good result is obtained ; moreover, one drill will cut thousands of grooves, and this method has been adopted for use here. Satisfactory circles, obtained by either method, will retain pure acetone, or solutions containing efficient wetting agents in sufficient concentration to ensure complete spreading of a small drop. In cleaning such slides, it will obviously be necessary to avoid the use of abrasives, but traces of chemicals in the grooves will be very unlikely to affect the issue on the flat circular area. Three circles of approximately 12 mm. diameter can easily be worked on a 3×1 inch slide without making it fragile, provided the grooves are 1 to 2 mm. wide. A diagram giving dimensions is provided in Fig. 1.

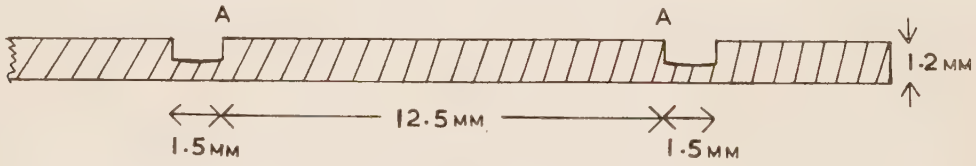

FIG. 1.

Vertical, longitudinal section through part of a slide, showing depth of groove and other dimensions. A-A is diameter of circular area.

Ensuring an even deposit.

The surfactant to be used in this work has to fulfil four requirements : (*a*) it must facilitate spreading of the initial deposit ; (*b*) it must re-wet readily to facilitate spreading of the spore suspension which is added after the deposit has dried ; (*c*) it must have a negligible toxicity to the spores at the concentration to be used ; (*d*) it must be as chemically inactive as possible toward other ingredients of the preparation under test. Montgomery and Moore (1938) refer to the use of sulphite lye (goulac) which fulfils these criteria to a remarkable degree and would be ideal if it were not that its composition varies somewhat from batch to batch and hence results could vary from time to time and place to place. In an attempt to overcome this difficulty, and to eliminate the unknown nutrients present in sulphite lye, the use of methyl cellulose was introduced by Shaw and Miss English about 1944 and continued until 1950. As, however, this product was obviously inferior to sulphite lye as regards criterion (*b*) above, we have examined a number of readily accessible surfactants of various types but have found none to equal sulphite lye, although certain mixtures are very promising. Typical data for twelve surfactants relative to sulphite lye, employing strain E_1 of the fungus *Venturia inaequalis* (Cke.) Wint., are given in Table I. This strain, obtained by Kirkham in 1949 as a single conidial isolate from a fruit lesion on the variety Edward VII, combines high spore yields with a high percentage spore germination, which is not the case with most isolates.

Only the two Tritons, X100 and X155, and Lissapol NXA, proved acceptable and, of these, the first seemed the best, at least in the absence of toxicants. The combination of good wetting and emulsifying powers in the one material as in these Tritons and Lissapol NXA is an obvious advantage.

With slides adequately grooved and formulations containing a surfactant such as Triton X100, it is an easy matter to put on a standard volume from a micropipette, to spread it evenly over the circular area, and to spread a standard spore-suspension over the dried deposit. A final concentration of 0·0125 per cent Triton X100 is being used successfully at present.

Provision of spores.

Montgomery and Moore (1938) describe the production of conidia on sterilized apple wood. By 1943, Montgomery had adopted two-inch lengths of one- or two-year wood, peeled but not split.

TABLE I.

PERFORMANCE OF SURFACE ACTIVE AGENT SOLUTIONS ON GLASS SLIDES AND EFFECT ON GERMINATION OF SPORES OF *Venturia inaequalis*.

Surfactant.	Class.	Initial spreading on glass.	Spreading of spore suspension.	Percentage inhibition of spores at various concentrations.		
				0·1%	0·05%	0·025%
Sulphite lye	Anionic	Excellent	Excellent	—	1·0	—
Lissapol C	do.	Very good	Very good	97·6	91·0	73·4
MB320	do.	Poor	Moderate	100·0	100·0	100·0
Sulphonated Lorol	do.	Poor	Moderate	25·2	13·8	14·2
Aerosol OT	do.	Very good	Moderate	—	5·3	3·1
Cetavlon	Cationic	Very good	Very good	100·0	100·0	100·0
Cetyl pyridinium bromide ..	do.	Good	Very good	100·0	100·0	100·0
Triton X100	Non-ionic	Good	Very good	12·5	8·9	5·5
Triton X155	do.	Good	Good	9·1	5·4	2·7
Lissapol NXA	do.	Good	Good	—	8·4	7·8
Tween 85	do.	Poor	Moderate	2·7	2·8	0·0
Methyl Cellulose C450 ..	do.	Very good	Very poor	4·5	5·8	5·1
Methyl Cellulose MM10 ..	do.	Very good	Poor	9·4	9·1	4·5

Moreover, the optimum time for producing such conidia was shortened to eight days at 20° C. Kirkham has found that *V. inaequalis*, strain E_1, produces ample conidia in ten days at 18° C. on young apple wood, and has evolved the following method of maintenance and preparation, based on that described by Montgomery and Moore (1938). A stock culture from a single ascospore is maintained under medicinal paraffin at 5° C. ; agar slopes are made from time to time and renewed as soon as the appearance deteriorates. Cultures are made on autoclaved apple wood weekly ; spore production is usually excellent and no extra nutrient is required. After ten days, spores are shaken free of the wood under water and filtered through fine organdie muslin. The suspension is then centrifuged thrice for 30 seconds, resuspending in fresh glass-distilled water each time. This procedure has been followed for all the tests recorded in this paper, except for the variations described under each section.

As a speed of 3,000 r.p.m. was used up to 1950, and the effects of centrifuging were in any case unknown, germination has been studied after a standard treatment of 1,850 r.p.m. (540*g*) for 30 seconds, and after additional spinning down for five minutes at a much higher speed, seven such speeds being used. The results are summarized in Table II.

It will be seen that the excellent germination of the control spores, spun for the standard time at the standard speed, is in no way reduced by additional centrifuging with much greater force for a much longer time. The standard practice will now be to spin the spores at approximately 2,400 r.p.m. (900*g*) for 30 seconds, in order to ensure complete settling of spores, some of which may float when lower speeds are used.

Use of nutrients.

Although no nutrient was used in the test as described by Montgomery and Moore (1938), nor by Montgomery up to 1943, many workers have found that germination of spores of many fungi is better in nutrient solution than in glass-distilled water. The latter adds nothing which could interfere with the test, but the former gives the spores the better chance to germinate and hence the more exacting test of the candidate toxicant. We have now adopted a nutrient medium containing 0·1 per cent sucrose and 0·001 per cent trisodium citrate (Miller, 1949) for the final suspension of spores, as it gives

as good a percentage germination as an earlier nutrient, which contained five times the amount of sucrose, and a tenth of the amount of sodium citrate, introduced by Miss V. P. J. Clarke in 1949. Typical percentage germination of spores of *Venturia inaequalis*, strain E_1, in various nutrient solutions in comparison with percentage germination in de-ionized water only, are shown in Table III.

TABLE II.

PERCENTAGE GERMINATION* OF SPORES OF *V. inaequalis* CENTRIFUGED AT VARIOUS FORCES.

Standard: 3 times for 30 seconds at 540*g.*	Standard + 5 minutes at						
	1,420*g.*	3,940*g.*	6,250*g.*	11,100*g.*	15,650*g.*	25,000*g.*	27,500*g.*
97·0	95·3						
95·3	95·0	—	—	—	—	—	—
89·3	90·0						
90·0	87·7	—	—	—	—	—	—
92·7	91·7						
92·3	91·0	—	—	—	—	—	—
95·0		93·0	93·7		95·0		98·7
94·0	—	94·0	94·0	—	94·0	—	97·0
92·0				93·0		93·5	
93·3	—	—	—	90·7	—	93·7	—

* Each value is the mean from three circles (one slide).

TABLE III.

GERMINATION OF SPORES OF *V. inaequalis* IN VARIOUS NUTRIENT SOLUTIONS AT 18-19° C. AFTER 42 HOURS.

	Spores suspended in	Percentage Germination.	
		1st Trial.	2nd Trial.
1.	0·5% sucrose 0·0001% citrate*	86·7	89·3
2.	0·5% sucrose 0·001% citrate*	83·7	87·9
3.	0·1% sucrose 0·001% citrate*	88·7	89·0
4.	Rain-water (collected in glass)	65·0	73·5
5.	De-ionized water only	75·0	81·8

* Trisodium citrate ' AnalaR '.

Period of incubation.

The duration of the test, i.e. the stage at which the count is made, will be determined by the rate of development of the germ tubes, and is influenced by the time and temperature of incubation. In the case of *V. inaequalis*, strain E_1, there appears to be an increase in percentage germination at 18° C. from 6 to 12 hours, but further increases at 24 hours and longer are relatively small in the absence of toxicants (Table IV).

When cupric ions (as copper sulphate) are introduced, however, germination is retarded, and, as can be seen from Table V, there was, on three occasions out of four, a considerably higher germination at 42 hours than at 20 hours.

It is very unlikely that any significant increase in germination over that recorded at 42 hours could have occurred subsequently. In any case germ tubes tend to become entangled if left too long, which makes counting more difficult and less accurate.

TABLE IV.

GERMINATION OF SPORES OF *V. inaequalis*, IN 0·5 PER CENT SUCROSE AND 0·0001 PER CENT CITRATE AT 18-19° C.

Period in hours.	Percentage germination.*
6	87·4
12	92·1
24	93·2
48	93·9

* Each value is the mean from twelve circles (four slides).

TABLE V.

PERCENTAGE GERMINATION* OF *V. inaequalis* SPORES HELD AT 18° C. FOR 20 OR 42 HOURS IN PRESENCE OR ABSENCE OF COPPER IONS.

Medium.	Test No.	Duration in hours.	
		20	42
Nutrient solution plus 0·05% sulphite lye	1	88·0	95·5
	2	90·0	92·3
	3	92·7	97·0
	4	90·0	97·3
Nutrient solution and 0·05% sulphite lye plus 0·0005% cupric ions (as sulphate)	1	74·7	93·7
	2	91·3	94·0
	3	78·7	94·0
	4	73·7	93·7

* Each value is the mean from three circles (one slide).

From the present data it would appear that a period of 12-20 hours is sufficient to judge the capacity of spores of *V. inaequalis* to germinate in a nutrient solution at 18° C. with or without a surfactant, but that it is wiser to employ a longer period of incubation, e.g. 42 hours, when the effect of a candidate toxicant is being studied.

Counting.

One of the major problems involved in laboratory tests is the fatigue consequent upon long periods of counting germinated and ungerminated spores under high-power magnification of an ordinary microscope. For spores of *V. inaequalis* or *V. pirina*, a magnification of 400 diameters is desirable with a good depth of focus. We have found the Vickers Projection Microscope to provide a fully adequate image of these spores on the normal screen and to permit prolonged periods of counting without undue fatigue. The light source is brilliant and constant, but there is no heating-up and spores can be incubated for a further period and re-counted if necessary. Doubtless a simpler, and cheaper, instrument could be devised for the task without sacrificing any of the advantages, possibly adding an automatic racking device, and bringing the whole of the manipulations within easy reach of the operator.

Discussion.

The original method of Montgomery and Moore (1938) had passed through many vicissitudes by 1950, and not all the modifications made had proved valuable. The basic problem—the provision of satisfactory slides—seems now to have been solved, and the fatiguing method of assessing germination under a binocular microscope has been superseded by one much less tiring. Few surfactants appear likely to be of use for the method, but one or two alternatives have been found to sulphite lye, which in most ways is excellent for the purpose and which some may prefer to retain.

The absence of deleterious effects of centrifuging at high speeds is not only a tribute to the strength of the conidial wall but also evidence of the stability of the contents even when the wall must be saturated with water. Clearly, this stage in the preparation of the conidia for tests is not as harmful as had been feared.

The use of nutrients is more debatable, and it may be possible to work with lower levels of sucrose than those employed here. The difficulties are well illustrated by the work of Manten *et al.* (1951) who found that growth of *Aspergillus niger* on a Czapek-Dox agar was largely inhibited by an iron salt of 8-hydroxyquinoline, whereas the same fungus grown on malt-agar was entirely unaffected by this chemical. The explanation offered by these workers is that the solubility of this iron complex, while adequate to inhibit growth of this fungus on the less complete medium, is too low to allow the minimum concentration for toxicity in the more complete medium. As these workers used the roll-culture technique (Manten *et al.*, 1950), it is impossible to say whether this effect would be shown in a true spore-germination test. But Miller (1950) found that the ED_{50} of certain copper, zinc, and nickel inorganic salts against *Sclerotinia fructicola*, and of Bordeaux against *V. inaequalis*, varied directly with the concentration of several nutrients, including sodium citrate. As toxicants of very low solubility have an obvious advantage as protective fungicides, i.e. will not easily leach away, it would be undesirable to conduct tests in a medium which made it possible for the test-fungus to survive unharmed in a saturated solution of a toxicant which, nevertheless, was highly toxic to the same spores under natural conditions where only a poor supply of nutrients is likely to be available. That some nutrients are supplied by the leaf in the orchard is indicated by the finding that tests on leaves always gave an inferior value for toxicity of a given chemical than similar tests on glass slides (Marsh, 1938), so that the slide-test ' flattered the fungicide '. Hence, it is desirable not to render the spore hypersensitive by germinating it in the purest water obtainable, nor to render it hyperresistant in a very complete medium, but to use only so much nutrient as is needed to provide a high percentage, in the region of 90 per cent, germination in the absence of toxicants. Although Montgomery and Moore (1938) added no nutrient as such, their surfactant, sulphite lye, contains up to 2 per cent sugars as well as 5 per cent lignin sulphonates and would undoubtedly provide a source of carbon for germinating spores. It is, however, difficult to escape the conclusion that surfactants of simpler, better-known, and more constant composition than sulphite lye possesses are less likely to lead to chemical changes on the slide. The view is taken by the present authors that the aim is reproducible results, and that the use of effective surfactants and a minimum of nutrients is essential to that end.

It is not suggested that the glass-slide spore-germination test, modified as described above, is yet as perfect as it could be, and further studies are in progress which may lead to more improvements.

Acknowledgements.

The authors are greatly indebted to Dr. H. B. S. Montgomery, Dr. M. H. Moore, and Mr. D. S. Kirkham for advice and criticism during the course of the work, and to the last-named for the provision of cultures of *V. inaequalis*, strain E_1.

Summary.

Modifications in the glass-slide germination technique of Montgomery and Moore are described, for use especially with *Venturia* spp.

Slides with circular grooves having sharp edges to the inner circle are advocated, and the methods of cutting these are outlined.

Twelve surfactants were compared with a standard sulphite lye solution, for wetting, rewetting, and inhibition of spore germination. Triton X100, Triton X155, and Lissapol NXA proved the most successful.

Methods of providing spores for suspension, and the negligible effect on germination of centrifuging these suspensions even at high speeds, are described.

Increase in percentage germination has been shown to occur in suitable nutrient solutions over that obtained in de-ionized water only. Spore germination in nutrient solution was almost complete at 6 hours, whereas in the presence of cupric ions germination progressed up to 42 hours.

Counting has been simplified and made less fatiguing by the use of the Vickers Projection Microscope.

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Part IV

BULLETINS FOR FRUITGROWERS

FIVE NEW APPLE ROOTSTOCKS

By A. P. PRESTON

The rootstock is one half of the tree and its influence on earliness of bearing, ultimate tree size, and cropping is well known. It has long been realized that there is much room for improvement in the present range of apple rootstocks ; some are shy rooting and behave poorly in the nursery, many make slow bearing trees in the plantation, even when lightly pruned. Some, like M.IV, produce heavily bearing trees that have only poor anchorage and often require staking throughout their plantation life. Furthermore, all the present series are susceptible to the Woolly Aphid and this is a very serious disadvantage in Australia, South Africa, and many other parts of the world, where this pest overwinters on the root system and resistance to it is therefore an essential attribute of a good rootstock.

It is not surprising, therefore, that the breeding of new rootstocks has been considered a very important line of research and, as long as thirty years ago, R. G. Hatton of East Malling, collaborating with M. B. Crane of the John Innes Horticultural Institution, set about the long task of raising a new series.

Over three and a half thousand seedlings were raised from crosses, made by Tydeman at East Malling and Crane at Merton, between rootstocks of the Malling series and Woolly Aphid resistant varieties such as Northern Spy. These were subjected to exhaustive tests, in which a large team at East Malling—Massee, Garner, Beakbane, and others—were engaged, using specially developed techniques. Eventually, after some twenty-two years, twenty rootstocks, representing the whole range of vigour from dwarfing to very vigorous, as indicated by their root structure, were selected for field trial. Apart from their probable effect on the vigour of the scion, resistance to Woolly Aphid and propagation qualities were the main characteristics on which selection was then based.

After seven years of field trials under three carefully selected scion varieties, those that have continued to be highly resistant to Woolly Aphid under East Malling conditions have been sent overseas for further trial at research institutes ; they have been named the Malling-Merton series (abbreviated to MM. to distinguish them from the Malling (M.) series).

Four of these, MM.104, 106, 109, and 111, show promise as rootstocks for this country, probably being improvements on M.IV, M.VII, and M.II, *quite apart from the fact that they are resistant to Woolly Aphid.* A fifth rootstock, which is not so highly resistant, is also of interest here, because it induces trees that are not only very vigorous but also precocious ; it has been added to the Malling series as M.XXV.

The following brief descriptions of these five rootstocks, together with some cropping figures (Table I), are based on two field trials, on loam and sand respectively, with the scion varieties Cox's Orange Pippin, Jonathan, and Ellison's Orange. The trees, planted in November 1945, have been very lightly pruned, by the ' regulated ' method, and have already yielded five successive crops. Comparable trees on M.IX provide a standard for early bearing, on M.IV for high yield, and on M.VII, M.II, and M.XVI for the semi-dwarf, vigorous, and very vigorous groups respectively.

MM.104.

Trees on this rootstock have yielded as heavily as those on M.IV and are well anchored, being much superior to those on M.IV in this respect. On the loam they have made larger trees than M.IV, but are identical in size on the sand. It is an excellent propagator.

MM.106.

On the loam, trees on this rootstock are identical in size with those on the intermediate rootstock M.VII, but on the sand they are smaller and might make a more satisfactory dwarf tree than does

TABLE I.

TOTAL CROP OF COX'S ORANGE PIPPIN ON LOAM AND SAND IN LB. PER TREE, 1948-52, ON CERTAIN OF THE NEW AND OLDER ROOTSTOCKS.

Rootstock.	Sand.	Loam.
M.IX	22	72
M.VII	57	145
MM.106	**46**	**145**
M.IV	62	172
MM.104	**59**	**180**
M.I	45	104
M.II	44	111
MM.109	**44**	**112**
MM.111	**61**	**156**
M.XVI	67	96
M.XXV	**50**	**140**

Figures in bold type refer to the new rootstocks now being released.

M.IX where such soil conditions exist. On both soils trees on MM.106 are smaller than those on MM.104.

MM.109.

Trees on this rootstock are larger than those on M.II on both soils, but the difference is especially marked on the sand where they have withstood two severe summer droughts well. In yield and anchorage they closely resemble trees on M.II.

MM.111.

Trees on this rootstock are similar in size to those on M.II, but they have cropped almost as heavily as trees on M.IV, especially with Cox's Orange Pippin on the sand.

M.XXV.

Trees on this rootstock are larger and have cropped more heavily than those on M.II ; on the loam they are as large as trees on M.XVI and heavier cropping. Its root structure suggests that it will ultimately make a very vigorous tree. It has been outstanding for a rootstock of this vigour group, in inducing the early development of fruit buds and in setting fruit.

Distribution in Britain.

These five rootstocks were distributed to large-scale rootstock raisers during the winter of 1952-53 for multiplication in Britain, and trees on them are likely to be available to fruitgrowers in 1957.

Trial under commercial conditions.

The trials we are carrying out at East Malling cannot in themselves indicate the best rootstocks for use in this country, though further information will be accumulated from them as the years go by and they are being supplemented by another experiment in Kent and a further one at the Experimental Horticulture Station at Luddington, Warwickshire. The final verdict must depend on their performance under the conditions of commerce. To this end, several growers in the chief fruitgrowing areas have planted demonstration sets of trees on their farms and further sets will be planted next season. Growers will thus be able to see for themselves how trees on these new rootstocks compare with those on the established ones under a wide range of soil and climatic conditions. These demonstrations will be a valuable supplement to our own trials and will help to give a definite lead as to the most suitable planting distances.

After nearly thirty years of critical selection, we have chosen these five rootstocks as worthy of extended trial ; it is hoped that growers themselves will decide which of them will best serve their own particular needs, by making trial plantations of trees on them as soon as they are freely available.

Summary.

A description is given of the history and behaviour of five new apple rootstocks that are being distributed for large-scale commercial propagation.

IRRIGATION REQUIREMENTS OF FRUIT ORCHARDS

By W. S. ROGERS and J. E. GOODE

Orchards in parts of England suffer seriously from drought in some years, and at East Malling it has been shown that apples can be increased in size by irrigation, even in a wet year. In order to know when to irrigate and how much water to apply, three main factors—the plant, the climate, and the soil—must be considered.

A useful approach is to strike a ' water balance sheet '. Water gains are represented by rainfall and irrigation ; water losses, by evaporation from the soil and transpiration from the leaves of the tree and cover crop. And the soil block occupied by, or available to, the roots provides a reservoir from which a definite amount of water can be drawn.

The soil moisture deficit.

The amount of evaporation and transpiration largely depends on the sunshine and wind ; and a useful formula, worked out by Dr. H. L. Penman of Rothamsted Experimental Station, has enabled the calculation of a figure termed the ' potential transpiration ' from standard meteorological records. The figures for potential transpiration refer directly to grass and similar low crops providing a complete vegetative cover of the ground and whose roots have access to an unrestricted water supply. Figures for the average potential transpiration for each month based on meteorological records for the past 25 years are available for any district from the National Agricultural Advisory Service. If the monthly potential transpiration exceeds the monthly rainfall, the difference between them represents the estimated soil moisture deficit.

Now, during the winter months rainfall normally exceeds evaporation and transpiration, and the soil water reservoir becomes filled to the ' field capacity ', i.e. the amount of water held after free drainage. From April to September, however, transpiration commonly exceeds rainfall. It is thus generally useful to begin calculating the monthly soil moisture deficit from April onwards, and to continue month by month getting a cumulative total deficit, until September.

An example using the average potential transpiration values for central Kent and the rainfall for 1952 will make the method easier to understand.

	Apr.	May.	June.	July.	Aug.	Sep.
(*a*) *Average* potential transpiration, inches ..	2·00	3·25	4·00	4·05	3·30	1·80
(*b*) Rainfall for the month, in. (1952)	1·06	1·02	1·15	0·67	2·85	3·20
(*c*) Deficit (*a*—*b*), in.	0·94	2·23	2·85	3·38	0·45	—1·40

Since the actual transpiration for any period varies according to weather conditions during that period it is advisable to correct the *average* potential transpiration value, at the end of each month, using the potential transpiration figure calculated from the actual weather data for that particular month. This figure, available one month later from the National Agricultural Advisory Service, is termed the *estimated** potential transpiration for the month in question.

	Apr.	May.	June	July.	Aug.	Sep.
(*d*) *Estimated** potential transpiration, in. (1952)	2·25	3·60	4·15	4·15	3·15	1·75
(*e*) Correction to be applied to deficit (*d*—*a*) ..	+0·25	+0·35	+0·15	+0·10	—0·15	—0·05
(*f*) Corrected deficit (*c*+*e*), in.	1·19	2·58	3·00	3·48	0·30	—1·45
(*g*) Cumulative deficit, in. (i.e. sum of monthly deficits from April onwards)	1·19	3·77	6·77	10·25	10·55	9·10

The water balance is shown here for monthly figures but the deficit can be followed more closely by working out the balance for half-monthly periods using half the average potential transpiration and of course the rain for the appropriate period. The correction can be applied only at the end of each month. The cumulative deficit can never become negative ; zero deficit is field capacity and any excess rain or irrigation water once field capacity has been reached is lost as drainage.

* The term *estimated* potential transpiration is here used in a special sense, distinguishing it from the *average* potential transpiration ; but it should be noted that all the potential transpiration data, and moisture deficit data derived from them, are in fact estimates.

Research is at present being undertaken to determine how nearly this method of estimation of soil moisture deficits is applicable under various systems of orchard soil management, and the following discussion is based on our recent investigations.

As already stated, the ' potential transpiration ' is based on a short crop covering the ground. Trees, presenting a larger surface area, tend, under similar climatic conditions, to lose more water than a short crop. Hence a mature orchard in grass may lose about 10 to 20 per cent more water than would be lost from a short crop alone. This, however, is not a serious difference, and the potential transpiration figures will serve as a good working approximation of water loss provided that at no time are the soil moisture reserves so depleted that grass or tree transpiration will be reduced through lack of water. Once this occurs actual losses will be less than the potential transpiration losses from the orchard and the calculated deficit will be higher than that existing under the trees. It is therefore important to know to what extent the stored water in the root zone of trees and grass will suffice to meet full transpiration needs.

The soil reservoir.

The amount of water available to plants in a soil—that is, the amount between field capacity and wilting point—is found to vary from 1 to 2 inches per foot depth of soil. The finer-textured soils generally have the higher values, and coarse sandy soils may have very small water reserves. The total water reserve will thus depend on the depth of soil exploited by the roots. In a soil fully occupied by tree roots to a depth of 5 ft., the available water, assuming an average of 1·5 inches per foot depth, will be 7·5 inches, i.e. up to 7·5 inches of water could be withdrawn before the trees wilted. If only 2 ft. of soil were available to tree roots (if, for instance, the depth of rooting was limited to this by rock or chalk), the water reserve would only be 3 inches.

When to water.

Research here and elsewhere suggests that it is undesirable to let the tree reach the wilting point, and that it is beneficial to apply water when about 50 per cent of the available water has been withdrawn. Thus in the first example given above, with a water reserve of 7·5 inches, an irrigation of about 2 inches would be desirable when the deficit approached 3 to 3·5 inches. Irrigation water should be applied in known amounts, so that the necessary reduction in deficit can be made in the water balance sheet.

It is not considered advisable to satisfy a deficit completely by irrigation, since a rainfall immediately following would be wasted in drainage, and with it certain nutrients. Hence ½ to 1 inch deficit is probably best retained.

For trees, irrigations of less than about 2 inches of water at a single application are probably uneconomical, in that the proportion of water reaching the major part of the tree root zone becomes very much less as the amount applied decreases. Irrigation may, however, need to be reduced in amount and applied more frequently on light sandy soils, particularly if they are shallow. Present work on a sandy soil indicates that on such soil a maximum deficit of 2 to 3 inches should not be exceeded and that irrigation should be applied in amounts of 1½ to 2 inches.

An advantage to be gained by maintaining the soil moisture deficit at a low level, quite apart from improved crop production, is that a soil which is not completely exhausted of available moisture permits better penetration of water than a dry one. It should also be stressed that the transpiration loss calculations are only valid when the deficit is low.

Cultivated orchards, in drought years, will suffer less serious deficits than similar orchards in grass. In fact, the deficit under young trees in clean cultivation will probably be two-thirds, or less, of that under similar trees in grass.

The grower who wishes to keep a moisture balance sheet for his orchards must therefore decide how nearly his orchards compare with the full soil cover of a short crop for which the potential transpiration losses strictly apply, and, until fuller information is available, he can use the above data to apply an approximate correction.

Much research evidence suggests that, for maximum growth and cropping, the transpiration demands on a tree must be met by an uptake of water equal to these demands. During the summer, transpiration rates are high and therefore the aim should be, as far as possible, to maintain the soil moisture supply at a level that will meet these high transpiration demands. Later in the season, reduction of soil moisture content may not be harmful.

The use of soil moisture tensiometers.

Where a precise and continuous indication of soil moisture conditions in a given location is desired, soil moisture tensiometers can be very helpful. It has recently been shown that tensiometer readings

are related to the amount of available water, approximately as follows, over quite a range of medium-textured soils :

Percentage of water available	100	50	20
Soil moisture tension (centimetres of mercury)	4	20	60

Thus, to maintain at least 50 per cent of the soil moisture available to trees, water should be applied when the tension at the desired depth reaches 20 cm. Hg. For full information it is desirable to have tensiometers at at least two depths, say 12 inches and 36 inches in a deep soil, or 12 inches and 24 inches in a shallow one. If only one tensiometer is used, a depth of 12 inches is generally suitable. Tensiometers are also useful for checking the depth of penetration of irrigation water. They are simple to use, and will give reliable results if the makers' instructions are carefully followed.

General conclusions.

As a result of recent research, growers are now in a position to calculate the water status of their trees on a rational basis, using data on :

(*a*) The depth of soil available to the roots (found by auger borings or by digging a trench).
(*b*) Rainfall measurements, preferably in an open space near the orchard concerned, and
(*c*) Potential transpiration estimates, available for each area.

The use of soil moisture tensiometers can also supplement, or replace, such information.

It must be emphasized that the recommendations given are of a provisional nature. In particular the relation of the potential transpiration of a full grass cover to water usage of trees of different sizes, and trees in various cover crops, needs further research, which is now in progress ; but within limits it is now possible to tell if and when orchard trees are in need of water, and to ensure that any water applied is not wasted.

Summary.

The use of a ' water balance sheet ' for fruit plantations, based on rainfall, transpiration and soil data, and the use of soil moisture tensiometers to supplement or replace such calculations are described.

It is provisionally suggested that irrigation, when about 50 per cent of the available soil water has been used, is desirable if maximum growth, yield, and fruit size are required. The economics of irrigation are not dealt with in this paper.

DOUBLE-WORKING PEARS AT BUDDING TIME

By R. J. GARNER

When certain pears, notably Williams' Bon Chrétien, are worked direct on quince rootstocks they have weak unions, which may break off clean either in the nursery or years later in the plantation. Sound trees are readily constructed by double-working, which can be done in one operation. The method is described in detail in this Station's Annual Report for 1943, page 80.

Though double-working by forming two whip-and-tongue grafts at one time is readily accomplished, some tree raisers find it irksome and it is believed that a simplified technique might prove welcome. At the suggestion of Dr. F. R. Tubbs, a method for use at budding time (Fig. 1) was devised in 1950. A budless shield from a shoot of the variety to be used as intermediate is inserted into the incision in the rootstock, followed by the normal bud shield of the upper scion. It is proposed to term this process ' double-shield budding '.

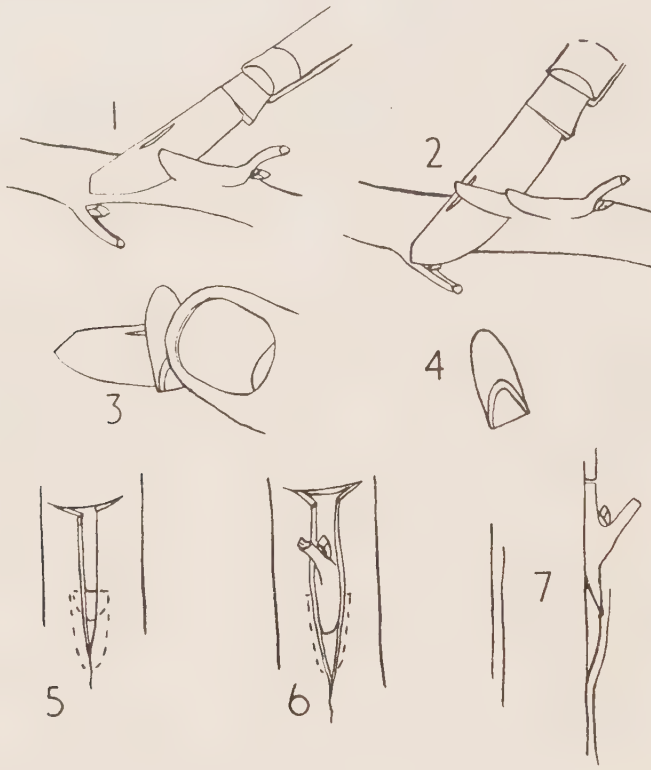

FIG. 1.

Double-shield budding.

1. A shallow cut in a shoot of Beurré Hardy.
2. A second cut to procure the budless shield.
3. Shield held between knife and thumb.
4. Outer view of prepared shield.
5. Dotted line shows position of shield after insertion in the quince rootstock.
6. The Williams' Bon Chrétien bud inserted above and overlapping the Beurré Hardy shield.
7. Diagrammatic side view section of shields.

Seventy-six trees of Williams' Bon Chrétien, with Beurré Hardy intermediates on Quince A, were raised by the new technique alongside single-budded trees worked direct on Quince A. The trees were measured and weighed when two years old and the breaking strain of the unions was recorded. Double-worked and single-worked trees were of similar size, but the former had the stronger unions.

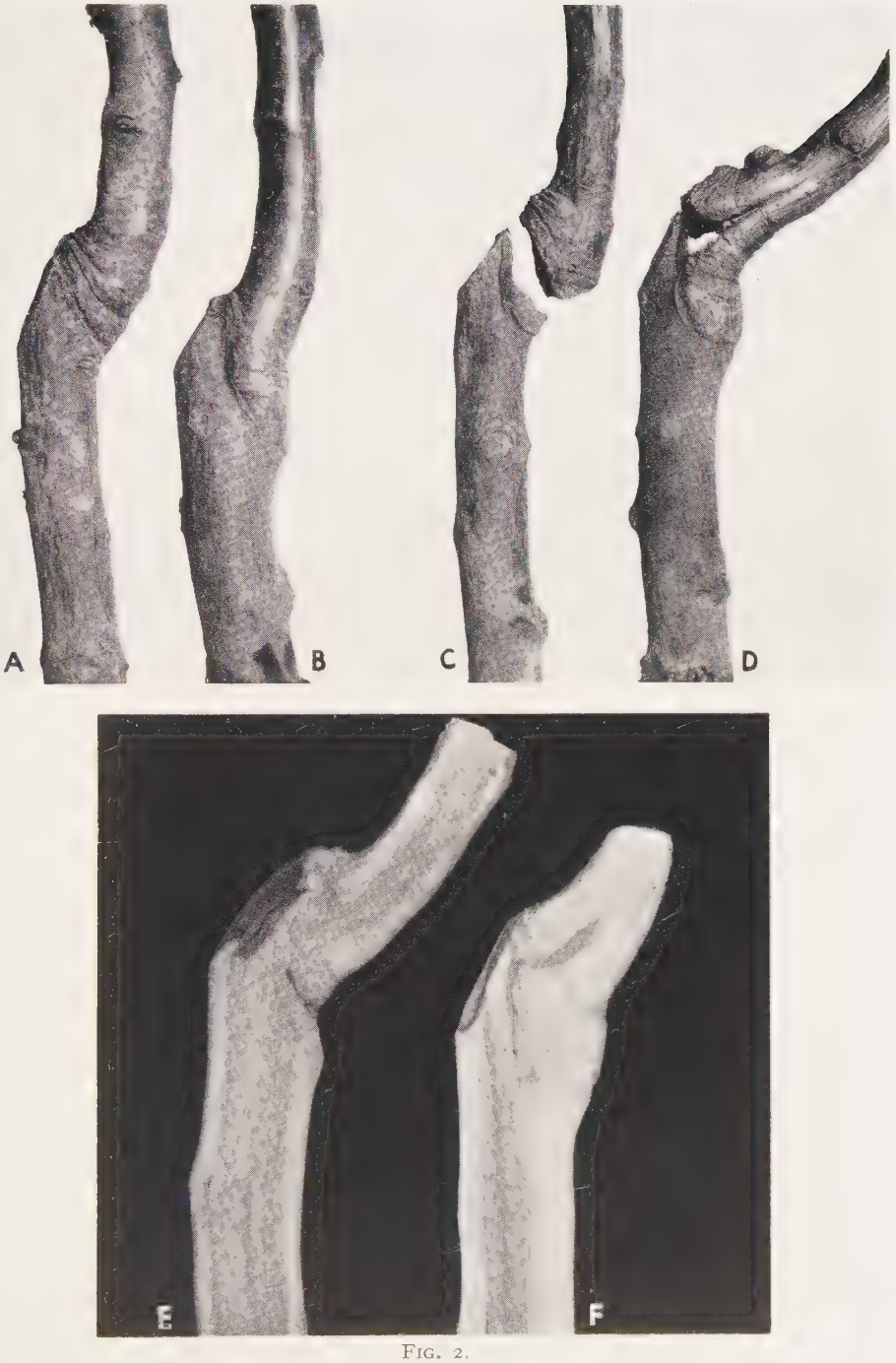

Fig. 2.

Two-year Williams' Bon Chrétien pears on Quince.

A. Normal budded tree.
B. Double-worked tree with intermediate shield of Beurré Hardy.
C. Broken union of normal budded tree.
D. Part broken union of double-shield budded tree.
E. Internal view of normal bud union. Note brown line at junction and lack of thickening below.
F. Double-shield union. Note sound junction and thickening of rootstock stem.

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Unions formed by double-shield budding may be recognized by their shape and the thickening of the rootstock immediately below the union (Fig. 2). After sawing down through, and planing the surfaces, the weak junction of the single-bud is clearly seen as a brown line, and there is no smooth joining of rootstock and scion. The double-shield union shows a good junction and much new thickening of the rootstock and intermediate.

Whilst double-shield budding to overcome incompatibility has only been in use for two seasons, the simplicity of the method appears to warrant its consideration by tree raisers.

Summary.

A description is given of the construction of reliable unions of Williams' Bon Chrétien on quince by a new method termed ' double-shield budding '.

NOTES ON SOME STRAWBERRY VARIETIES

By DOROTHY J. WILSON

Many trials have been carried out at East Malling to compare different stocks of the main commercial strawberry varieties and to evaluate the performance of virus-tested clones. These trials have been of modern design, using small plots suitably replicated, and the following notes are all based on the evidence of at least two trials, usually extending over several years. Crop figures quoted are derived from spaced plants (36″×18″) from which runners have been removed. Higher yields have often been obtained from matted rows (Rogers and Modlibowska, 1950). The index numbers refer to virus-tested clones.

In order to maintain the performance of virus-free stocks they have been kept separate from virus-carrying stocks, so there has been no direct comparison between the two groups of varieties. Huxley M.44 has been used as a standard of comparison for virus-carriers, and Royal Sovereign M.40 and M.48 for virus-free stocks. Auchincruive Climax M.46 has been included in both series of trials because it is virus-free and also has a fair degree of tolerance to Yellow-edge.

Sound, marketable fruit has throughout been picked into two grades, grade 1 comprising fruits over $\frac{7}{8}$″ in diameter and grade 2 smaller fruit. Damaged and rotten fruits, of whatever size, have always been picked as grade 3. Yields quoted refer to marketable fruit only, unless otherwise stated.

Huxley M.44.

This clone carried virus 1, the mild crinkle virus, when it was released in 1944. It has been continuously in cultivation at the Research Station since its selection. In one trial in 1948 it cropped at a record rate of almost 7 tons per acre. An average cropping rate for several years has been over 4 tons per acre. These trials were not cropped in their maiden year, but the mean includes a fifth crop from six-year-old plants and the crops of two trials in 1949 which was a very dry year.

Huxley has shown itself particularly sensitive to water shortage. The reliable water supply in the Wisbech area is undoubtedly one of the reasons for its success there. The crop at East Malling was low in 1949 and 1951, both drought years, when fruit size suffered considerably. In better years as much as half the marketable fruit has been of grade 1 size.

Madame Lefebvre M.49.

Although this clone contains virus 1 and another undescribed virus, it has a more favourable virus-status than any of the Madame Lefebvre stocks which have so far had full-scale field trials.

The first fruits ripen at least 3 days and sometimes 8 days before Huxley and the crop is over within 3 weeks. The heaviest crop recorded was at the rate of 93 cwt. per acre in 1948. The mean of thirteen crops (not including maidens) from trials in the last six years has been 60 cwt. per acre, of which 43 per cent was grade 1 fruit. Maiden crops have usually been about 5 cwt. per acre.

This variety is very susceptible to Strawberry Mildew and in some years a high proportion of the crop has been spoilt by this disease. Efficient sulphur dusting in April and May is therefore vitally important. One of the earliest varieties to flower, its blossoms are liable to spring frost damage.

Commercially, its value lies in the size of its early fruits, although many of them are often distorted by incomplete pollination. Flavour has never been considered good and the small fruits in the second half of the season are not attractive.

Perle de Prague M.45.

This stock carried virus 1 when it was tested in 1943 and 1949. In some years, picking has begun on the same date as for Madame Lefebvre, but it has more frequently started a couple of days later and gone on a week longer.

Crops have always been heavy, the average of nine recorded since 1948 being 87 cwt. per acre. 30 per cent of this fruit has been of grade 1 size, most of it coming in the first fortnight of picking. Sample counts of fruit in a given weight of each grade have shown Perle de Prague to be slightly smaller than Madame Lefebvre in most years.

Of much better dessert quality than Madame Lefebvre and much more resistant to Strawberry Mildew, Perle de Prague is softer and more easily damaged by handling or transport.

The flowers of Perle de Prague are the first to open in the spring and, standing well above the foliage, are liable to damage by spring frosts or cold drying winds which may cause the earliest blossoms

to shrivel. As the blossoms sometimes suffer severely from Strawberry Blossom Weevil, it is always advisable to add DDT to the pre-blossom sulphur dust.

Early Cambridge S.230.

Like Madame Lefebvre M.49, this clone contains another undescribed virus besides virus 1. It has, however, shown more frequent virus breakdown from further infection in the field, and many plants, in the two trials so far completed, had to be replaced for this reason and because of Verticillium Wilt. In one trial there were considerable attacks of the stem eelworm, *Ditylenchus dipsaci*, and Early Cambridge was one of the varieties affected. The two crop records from this trial are therefore based on the weights from only three replicates. The variety is included in a third trial from which the first crop was picked in 1952.

In spite of its name, it cannot be considered an early variety. Here in two years its season has been the same as Perle de Prague and in two it has coincided with Huxley.

Plants in their maiden year cropped at 9 cwt. per acre and the other five crop records available give a mean rate of 69 cwt. per acre, of which, on average, 41 per cent was grade 1 fruit. The first grade fruit has had the same average size (number per unit weight) as Huxley and Lefebvre, but the second grade fruit has been smaller. Like Perle de Prague it tends to prolong its season with a succession of small but good quality fruits. Its flavour has usually been poorer and more acid than Perle de Prague, which it somewhat resembles in appearance, but it is firmer and stands handling better than that variety.

Jucunda S.241.

This stock of the variety so popular in Holland has been included in two trials, and has shown itself most unsatisfactory under our conditions. A carrier of virus 1, it suffers to some extent when further infected by virus in the field, and has been considerably affected by attacks of stem eelworm in one of the trials.

It is a late variety starting usually five days after Huxley. The heaviest crop recorded was at the rate of 42 cwt. per acre ; apart from this, yields have been extremely poor. The bulk of the fruit has always been very small, acid, and of poor flavour. The ease with which ripe berries can be picked without the calyx is an advantage to jam-makers, but unless a much heavier-cropping stock can be found the variety is of little value.

Royal Sovereign M.40 and M.48.

These stocks are essentially the same in that M.48 was propagated from a re-tested plant of M.40. Both are virus-free clones.

Crops have been round about 3 tons per acre, a high proportion of the fruit, sometimes almost 70 per cent, coming in the first grade. There is often quite a large amount of rotten or damaged fruit in addition to the saleable crop, and some of this might be saved by picking over every day, instead of only every second day as here. The variety is very susceptible to *Botrytis* in damp weather, and in some years has been severely attacked by ground beetles, though this is probably a question of location and season rather than varietal susceptibility.

As a dessert berry, the quality of this variety still surpasses that of any others grown here.

For best results with Royal Sovereign it is important to prevent Mildew, to which the foliage is particularly susceptible, by regular sulphur dusting before and after cropping.

Bradley Cross S.55.

This is a virus-free clone. Its season is practically the same as that of Royal Sovereign and, although its total crop weights have sometimes exceeded Royal Sovereign, the amount of marketable fruit has been about the same from the two varieties. A rather smaller proportion of the crop has qualified for grade 1, probably because many of the larger fruits split into two fangs, before they are fully ripe, and begin to rot inside the split. Besides, the petals frequently persist on the ripening fruit and not only detract from its appearance but often rot and cause rotting of the fruit where they touch it. This is a serious drawback, as in some seasons much of the best fruit is spoilt in this way.

Clean ripe fruits have a good flavour, but it is not considered quite so good as Royal Sovereign.

The variety is prone to a form of root-rot, the cause of which is not fully known, but it appears to suffer less from virus infection in the field than Royal Sovereign.

Auchincruive Climax M.46.

As the M.46 clone is virus-free when planted out and Climax is partially tolerant to Yellow-edge, it has been included in trials with Royal Sovereign as well as with virus-carrying varieties.

Its season usually begins three or four days later than Huxley and a week to ten days later than Royal Sovereign. The crop has reached practically 6 tons to the acre, but the average of eight cropping rates has been just over 4 tons. The first main crop, i.e. from plants in their second year, has usually contained about 50 per cent of grade 1 fruit ; in succeeding crops the proportion has sometimes, but not always, been smaller. The mean size of the first grade fruits tends to be a little smaller than that of Sovereign and about the same as, or a little larger than, that of Huxley.

As a market variety, Climax is considered much superior to Huxley. Its flavour and appearance are good and its firm texture enables it to stand handling better than Royal Sovereign. Another advantage is that ripe fruits will hang on the plant for a day or two without becoming soft.

The variety commonly produces an autumn crop and considerable numbers of fruits have ripened in favourable seasons. In one experiment where six plots were deblossomed in the autumn and six were not, the deblossomed plots twice gave about 10 cwt. per acre more fruit in the succeeding summers. This gain must be set against the cost of deblossoming and the loss of any autumn fruit.

Direct experimental evidence on the effect of Yellows on crop weight is not yet available, but it is worth noting that a half-acre experimental block, in which quite a large proportion of plants show transient Yellows, has given two excellent crops so far.

Conclusions.

For conditions such as ours, Auchincruive Climax seems to be the most paying variety at the present time. For a high quality early variety there is nothing to surpass Royal Sovereign, but it must not be grown anywhere near virus-carriers if its cropping is to be maintained.

Where isolation from virus-carrying varieties is not possible Madame Lefebvre and Perle de Prague are still useful, the latter especially for garden use or local markets. Early Cambridge appears to be less suitable for our conditions than for some other districts.

It is well known that the behaviour of strawberry varieties varies greatly from place to place and growers will find it worth while to consult the results of any local trials or to carry out their own. But it cannot be over-emphasized that virus-free stocks should be planted wherever possible and that they must be kept separate from virus-carriers, or their potentialities cannot be fully tested. The incidence of virus is still the main cause of deterioration in strawberries, and only by bearing this in mind and paying strict attention to aphid control measures, can reliable cropping be maintained.

Acknowledgements.

The author wishes to thank Dr. W. S. Rogers, who initiated the trials on which these notes are based, and the many other workers who have assisted in running them.

Summary.

Notes are given on the performance of eight strawberry varieties in recent trials at East Malling.

Reference

Rogers, W. S. and Modlibowska, I. (1950). Strawberry cultivation studies. III. Spaced and matted systems. *J. hort. Sci.*, **26**, 47-59.

VIRUS DISEASES AND THE PROPAGATION OF FRUIT TREES

By A. F. POSNETTE

Most nurserymen and fruitgrowers are now aware that virus diseases attack fruit trees as well as soft fruit crops, but few realize the serious dangers inherent in the present situation. Losses are seldom spectacular because not many trees die from virus diseases, and poor growth or cropping are usually attributed to other causes. It is probably as true as most generalizations to say that many virus-infected trees can be made to crop sufficiently well to satisfy the average grower, but the additional costs of production involved and the lower return per acre may well make the effort uneconomic except in high-price periods. A greater total production of fruit may not be in the growers' interests, but greater production of better quality fruit per acre would not only provide the grower with a greater margin of profit over production costs, but would free a proportion of orchard land for other crops. There are at present, however, many acres of virus-infected trees which are not cropping sufficiently well to satisfy the grower, and there are several virus diseases of cherries, for instance, so severe that even the best management cannot mitigate their effects. This is also true of diseases such as Stony Pit and Chat Fruit, which lower quality in pears and apples respectively.

Losses in orchards.

The state of chronic infection of many of our orchard trees has inherent dangers far beyond the present losses, however ; these dangers arise from two eventualities, one potential and one actually happening now. The potential danger is that diseases which now seem to be static, or to spread only slowly from tree to tree, may begin to spread more rapidly. The possibility of the virus becoming adapted to an insect already present, or of a new insect vector being imported into this country, is not so remote as it may seem. The most severe virus diseases, such as Rasp Leaf of cherry, are now scattered thinly through our orchards, but the comparatively few infected trees provide many foci from which rapid spread could occur if an insect vector were present. This is not entirely hypothetical : it has happened in recent years with peach and cherry viruses in parts of North America and is probably occurring to a lesser extent with Cherry Tatter Leaf in Kent. With most of the severe virus diseases, however, it remains a potential rather than an actual threat.

The immediate danger lies in haphazard methods of propagation. Viruses are graft-transmissible pathogens, and this means that all trees raised from infected scions or rootstocks will be infected throughout with any virus present in either. When an infected tree is used to supply budwood, or an infected stool to supply rootstocks, all the young trees propagated from them are infected ; and if scion and stock were carrying different viruses, the young trees would be infected with both viruses. If an intermediate graft were used to overcome incompatibility or as a stem builder, a third virus might be added.

Viruses may be transferred from one scion variety to another when rootstocks which have been budded or grafted, whether successfully or not, are later re-worked with other varieties or, still worse, are used in stoolbed propagation. New varieties, healthy when released, may quickly become infected when propagated by top-working on old varieties, as happened with the Lord Lambourne variety, for example.

Considering that all these procedures have been in common use without precautions against virus infection, it is not surprising that virus diseases are now widespread. Severe diseases have not been widely dispersed because symptoms are usually obvious both on the tree used for scion material and in the nursery ; it is those with inconspicuous symptoms and less drastic, but none the less pernicious, effects which have not been avoided. If there were no improvement in the system, the decline of our established varieties following the accumulation of mild viruses would only become apparent when it would be too late to avoid serious losses. No curative treatment for virus diseases on an orchard scale is in sight, and once an orchard is established with infected trees, the grower is faced with the unhappy choice of grubbing and replanting, or of making the best he can of a bad lot. The loss is sometimes aggravated by the fact that obvious symptoms may not develop for several years after planting ; furthermore, they may take the form of poor growth and cropping, involving the grower in unnecessary expense for additional fertilizers or even drainage schemes in an endeavour to overcome the supposed cause of the trouble.

Losses in nurseries.

We have considered so far the losses the fruitgrower is likely to suffer from virus diseases. The nurseryman, on whom the fruitgrower relies for the health of his planting material, is also affected in several ways. Starting with the propagation of clonal rootstocks, there is evidence that even a mild virus infection in the stoolbed can markedly reduce the yield of first grade rootstocks. In the next stage, virus infection is one of the commonest causes (apart from bad budding) of bud failure in the nursery (Fig. 1). This leads to re-grafting with another variety, which may be much more severely affected by the virus than the first, as when peaches are worked on infected plum stocks (Fig. 2). Infected plants usually make less growth than healthy ones (Fig. 3), resulting in a lower proportion of first-grade maiden trees and more runts to be grown on for another year or two. Sales are likely to be poor when cautious buyers, inspecting the nursery before ordering, see gappy rows of uneven plants. Finally, trees showing symptoms of virus disease would not be passed for export, and even if the symptoms were overlooked before despatch, further orders are unlikely to come from the recipient overseas.

What, then, can be done to minimize the danger of virus infection ? The complete elimination of virus diseases from planting material can be achieved only when research stations are able to release to the industry virus-tested rootstock and scion clones ; but the issue of these clones would not solve the problem unless propagators were prepared to co-operate in taking certain simple precautions. Although complete elimination is not a practical aim at present, a start could be made by limiting the propagation of those diseases causing visible symptoms,* so stopping the further degradation of planting material and gradually improving it. The precautions recommended fall into two groups : firstly, those concerning rootstocks and propagation methods, and secondly, those on which the selection of scion material should be based.

Precautions against rootstock infection.

Source of stock.

When planting a stoolbed or purchasing rootstocks for lining-out, *only* material certified by the Ministry of Agriculture in the same or the previous year should be used. If possible, inspect the material yourself in the summer and make sure that it is up to the standard you hope to maintain. Never use root suckers from established trees. In this connection it should be remembered that many so-called seedling stocks, particularly Mazzards, are in fact suckers.

Rogueing.

Look over the young growth on stoolbeds in June, paying particular attention to the older leaves at the base of the shoots, as these show the clearest symptoms and may be covered by later earthing up. Any plants with leaf symptoms should be grubbed or marked clearly with a stake for removal as soon as labour is available.

Stocks lined out for budding should be inspected when, or just before, they are being budded, and any showing virus symptoms should be removed.

Bud failures.

Under no circumstances should once used stocks be re-worked with another variety or used for stooling. Where necessary, they may be grafted with the same variety as the bud that has failed, preferably using scionwood from the same sources, but whenever the loss involved is not too great they should be destroyed.

Selection of mother-trees.

The careful choice of trees from which bud- or graft-wood is to be taken is of fundamental importance. The trees should be inspected at least once during the summer, preferably in July, for foliage symptoms, and again shortly before the fruit is picked, to ensure good yield and quality. This inspection is particularly important when graft-wood is to be taken later in winter ; bud-wood is usually taken at a time when foliage symptoms would be present, but infected and healthy trees are often indistinguishable when graft-wood is taken. Stony Pit in pears and Chat Fruit in apples, to mention only two diseases, cannot be avoided with certainty unless the scion-mother trees are chosen and *clearly marked* at or before picking time.

* For virus symptoms on cherries and plums see ' Virus Diseases of Sweet Cherries ', *Rep. E. Malling Res. Sta. for 1950*, p. 209, and ' Virus Diseases of Plums ', *Rep. E. Malling Res. Sta. for 1952*, p. 182.

Fig. 1.

Ten F12/1 mazzard stocks were worked with buds from a symptomless Early Rivers cherry tree later shown to be virus-infected. Six stocks were removed after the scion buds failed to grow, and four maidens trees remain.

Fig. 2.

Right : Peach infected with a virus from plum ; *Left :* healthy peach of same age.

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FIG. 3.

Ten F12/1 mazzard stocks were budded by the same operator in the same nursery row as those shown in Fig. 1 but with buds from a virus-free Early Rivers tree. Ten first-grade trees resulted.

The practice of taking scion-wood from nursery trees is deprecated unless special precautions are taken to avoid virus diseases which cause abnormal fruit but no leaf symptoms.

However carefully mother-trees are selected, infected trees cannot always be avoided. Some varieties show more obvious symptoms of certain virus diseases on young trees in the nursery than on older trees, and the greater ease of observation in the nursery is another factor which makes careful inspection there during the maiden year, and again in the second year if possible, an important second line of defence. It is obviously a great advantage when more than one mother-tree of any one variety is used, if the offspring of each are distinguishable in some way ; an extension of this leads on to the ' pedigree system '.

The pedigree system.

A pedigree system should be adopted if possible, by which is meant simply any system by which it is possible to trace with certainty the mother-tree from which any particular nursery tree was worked. The basic principle of progeny testing, so familiar to stock breeders, is then applicable, although here we are considering vegetative progeny. When several mother-trees are used and the maidens or two-year-old trees grown from them are compared, the propagator can considerably reduce virus diseases by discarding mother-trees which produce weak or abnormal offspring. Once tried, the advantages of a pedigree system are so obvious that it is seldom if ever abandoned ; the time involved in recording is a very small addition to that normally used in nurseries for rootstock and variety names. The simplest method is to have a single number or letter for each mother-tree, adding this to the variety name on the labels ; then instead of having a mixed lot of, say, 100 Napoleon 2-year-old cherries, worked from three different orchard trees but not knowing which came from which, the nurseryman would have perhaps 50 of Napoleon 1, 30 of Napoleon 2, and 20 of Napoleon 3. His notebook would show that the mother-tree Napoleon 1, which has given the best results, is the third tree in the fifth row of a particular orchard. This tree would be used for the bulk of the scion-wood needed the next year, Napoleon 2 and Napoleon 3 being discarded and replaced by Napoleon 4 and Napoleon 5, and so on. The result will be a gradual improvement in the quality of tree grown, and probably also in bud take.

Virus-tested trees.

During the next few years East Malling Research Station will be releasing virus-tested material for the propagation of some of the more important commercial varieties. This material, as it becomes available will, it is hoped, gradually replace untested trees as sources of scion-wood. In the search for completely healthy material, the problem of finding suitable symptomless trees for testing would be facilitated if nurserymen would develop their own mother-trees, material from which might be tested.

Summary.

The dangers inherent in the present situation, with numerous virus diseases present in orchards and fruit-tree nurseries, are discussed. Careful selection of rootstocks and scion material is needed to reduce the incidence of these diseases in new orchards, and the necessary precautions are described.

VIRUS DISEASES OF PLUMS

By A. F. POSNETTE

The health of the plum rootstocks in common use is safeguarded, at least to the extent possible by inspection, by the Ministry of Agriculture's certification scheme, but at present this does not include scion varieties, whose health is solely in the hands of the propagator. Clearly it is futile to ensure healthy stocks for diseased scions. The precautions necessary to avoid virus infection are discussed elsewhere in this report (see page 179). Our purpose here is to describe the virus symptoms which can be seen on plums ; those on cherries were described in the East Malling Research Station Annual Report for 1950, page 209.

Plum trees in general are, in comparison with other species of *Prunus*, tolerant of most of the viruses which infect them. In the course of virus-testing apparently healthy trees by grafting bark chips into peach and cherry, viruses have often been transmitted which cause severe symptoms in the latter hosts. These viruses, which are latent in plums and do not cause recognizable diseases in them, need not concern us in this bulletin although their presence is obviously undesirable, especially where plums are grown together with either peaches or cherries. The elimination of latent viruses can only follow the distribution of virus-tested clones in due course, but the spread of viruses which cause visible symptoms on plums can be checked considerably by a thorough roguing of rootstocks and careful selection of scion mother trees.

Diseases with leaf symptoms.

Line Pattern.

There are several viruses which cause yellow lines on the leaves, either in the form of bands along the veins (Fig. 1) or as wavy ' oak leaf ' patterns (Fig. 2). Considerable differences in symptoms occur also between varieties. Some develop conspicuous patterns with a virus which others can carry with practically no visible symptoms. Some suffer a reduction in vigour, while others are little affected, and there seems to be no correlation between the clarity of the leaf symptoms and the degree of stunting. Severely stunted trees with line pattern symptoms are, however, probably infected also with another virus, which, unlike the line pattern virus, has a severe effect on peach and cherry. So, although the line pattern viruses alone seem to have comparatively little effect on the growth of plums, their bright symptoms are important as a sign that the tree is virus-infected and that other viruses may have entered by the same channel.

Ring Spot and Shot Hole.

Yellow rings enclosing green areas, which later turn brown and drop out leaving ' shot holes ' in the leaf (Fig. 3) are caused by a virus. These symptoms resemble those produced by the canker-forming bacterium, *Pseudomonas mors-prunorum*, but bacterial spots are usually smaller and darker brown.

This virus causes some loss of vigour in certain varieties, including the rootstock clones Brompton, Common Plum, and Marianna.

Mosaic.

Several forms of angular chlorotic markings have been seen on plum leaves and the distinction between their various causes is still obscure. It seems almost certain that mosaic patterns can be caused by viruses, genetical mutations, insects, or mites, and further work is required before diagnostic symptoms can be described.

Leaf Roll.

An upward rolling of the leaves, which droop as though the tree were wilting (Fig. 4), is caused by a virus which may be the same as that causing Peach Yellows in the U.S.A. The leaves feel stiff and rattle when a branch is shaken. Some loss of vigour is associated with this disease.

Veinlet Clearing.

During experiments in 1952, a virus was transmitted by grafting from trees of two gage varieties, Denniston's Superb and Kirke's Blue, to Myrobalan seedlings which developed mottled leaves and

Fig. 1. Vein banding in Victoria plum.
Fig. 2. Line Pattern in Myrobalan.
Fig. 3. Ring Spot and Shot Hole in Ontario plum.
Fig. 4. Leaf Roll in Ontario plum, with normal leaves on left.
Fig. 5. Veinlet Clearing in Myrobalan, with normal leaf on left.
Fig. 6. Rough, narrow leaf of Switzen Prune, with normal leaf on left.

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FIG. 7. Bark splitting on Cambridge Gage.
FIG. 8. Variegation (not transmissible) in Bullace.
FIG. 9. 'Willow leaf' in Marianna, with normal leaf on left.
FIG. 10. 'Oak leaf' in Brompton, with normal leaf on left.

became extremely stunted. When held so that light shines through the leaf, it can be seen that the mottle is caused by a clearing or transparency of some of the small veins (Fig. 5). No such symptoms were noticed on the gages from which the virus originated, but they may have been overlooked and further investigation is required before we can say whether plums other than Myrobalan are affected. From the appearance of the Myrobalan seedlings, however, which are seldom stunted even by viruses which affect other varieties of plums, this veinlet clearing virus may seriously reduce growth.

Prune Dwarf.

The virus disease called Prune Dwarf in North America causes the Italian Prune and Lombard Plum to produce narrow, strap-like leaves. Similar symptoms have been seen on Switzen Prune in Kent (Fig. 6).

Diseases with bark symptoms.

Bark Split.

Evidence has been obtained recently that severe bark splitting (Fig. 7), followed by canker formation, is a virus disease. Symptoms are particularly severe on Ontario and on Cambridge Gage.

Bark splitting may start on one-year-old shoots, but it becomes more conspicuous with age. The rind splits down to the wood and, as the sides of the crack separate, light brown callus-tissue grows out to cover the exposed wood ; this results in roughened bark. Where splitting does not occur, the stem is often flattened, fluted, or otherwise distorted, and the stems of young trees may be thicker two or three feet above the graft union than they are at the base.

Stunting and early defoliation are associated with this disease, which may also be important in providing an entry for bacteria and fungi.

Plum Stunt.

Several virus diseases cause stunting in certain varieties, and viruses are probably the commonest cause of poor growth in plums. The name ' Plum Stunt ' has been given to a virus disease which also induces small, powdery, brown pustules on the young shoots. The proportions of wood and bark are affected, the wood being poorly developed and the bark thick and spongy ; probably for this reason, the branches are abnormally flexible and yet easily broken. (For a full description, see Crowdy and Luckwill, Long Ashton Research Station Annual Report for 1949, page 80.)

Bud-perpetuated diseases not caused by viruses.

Several leaf abnormalities which are not caused by viruses occur in plums. They are in the nature of bud-sports and are not transmitted through grafts, but, as these deformities are perpetuated in scion wood, care should be taken to ensure that bud and graft wood is not taken from trees showing abnormal foliage, or weak, unfruitful trees may result.

The commonest abnormality is some form of variegation, where part of the leaf is light green or white and part is normal (Fig. 8).

Other abnormalities affect leaf shape. In one type the leaves are abnormally narrow, like willow leaves (Fig. 9), while in another, the leaf margins develop irregular lobes which transform a Brompton leaf, for example, into the shape of an oak leaf (Fig. 10).

A third type of genetical abnormality takes the form of translucent spots which may later tear as the leaf expands, and usually turn brown. The spots later drop out and leave a ' shot hole ' condition resembling that caused by either the ring spot virus (see above) or by bacteria (*Pseudomonas mors-prunorum*).

Summary.

Six virus diseases causing leaf symptoms on plums, and two causing bark symptoms are described, together with three types of non-transmissible diseases with virus-like symptoms. The information is provided to help propagators to avoid infected material.

THE GREEN PETAL DISEASE OF STRAWBERRY

By A. F. POSNETTE

An example of the Green Petal disease of strawberry was demonstrated at the Members' Day on Virus Diseases on 2nd July, 1952, although we were not certain then that it was caused by a virus. This doubt has now been removed by successful transmissions of the disease by grafting. This virus differs from those causing Yellow-edge and Crinkle in its severity and its vector, which is still unknown but is almost certainly not the Strawberry Aphid. There is some circumstantial evidence that the green petal virus is spreading to strawberries from some other crop or weed, and reports of its occurrence may help in tracing its origin.

The main characteristics by which this disease can be recognized are :

Flowers with small, cupped, green petals and abnormally large sepals (Fig. 1).

Fruit which appears ' seedy ' and shrivels before ripening.

Foliage olive-green with the older leaves turning red in summer.

Sudden wilting and drying of the leaves (Fig. 2) occurs usually in late July or August, often followed by the development of a few very small, yellowish leaves. These miniature leaves may also appear in June or earlier, the time probably depending on when the plant became infected ; their presence in the autumn provides a useful distinction between this Green Petal disease and Verticillium Wilt.

Fig. 1.
Flower of Auchincruive Climax with Green Petal

Fig. 2.
Auchincruive Climax with Green Petal disease (left) and normal (right). Note shrivelled fruit, wilted leaves, and small young leaves. (Photographed in August.)

COMMON NAMES FOR CHEMICALS

By A. H. M. KIRBY

Not long ago, a leading growers' periodical commented unfavourably when growers were asked to give a trial to a new fungicide with the chemical name of N-trichlormethylthiotetrahydrophthalimide. Now this is by no means the longest name which could be, or indeed has been, given to a chemical, and we can all be thankful for the use of initials or, as in the case of this fungicide, a code number in place of scientific names. It was, of course, only natural that many people should ask for ' common names ' to be devised for new pesticides, and it may be as well to point out that research workers, including chemists, feel the need for such short terms long before growers do.

Arising out of recommendations made at the Commonwealth Entomological Conference in 1948, the British Standards Institution set up a Technical Committee to prepare a British Standard list of common names for established pesticides. This committee could well do with a short name itself, as it is called the Pest Control Products Industry Standards Committee. Representatives are drawn from four industrial organizations and nine government and scientific bodies, thus ensuring thorough, albeit rather slow, examination of all proposals, which may be made by any interested person or group. Liaison is maintained with the corresponding committee in the U.S.A. and with the Commonwealth countries, and selected names are pre-empted from use as proprietary names in these areas.

Mankind is at present investigating, by trial and error, the feasibility of using initials in place of long and complicated names, from C.I.G.S. to Unesco. Sometimes this makes confusion worse confounded, as is the case with F.B.I., which means such different things on opposite sides of the Atlantic. But some things are clearly labelled by initials and there is little prospect of change in these cases. This is true of certain pesticides, such as DDT, but it would obviously be undesirable to push this method very far, as some chemicals, though of very differing natures, have the same initials, and, anyway, the non-chemist at least will soon find it hard to remember the significance of each set of initials.

In some cases, prime manufacturers have invented short names for their products. These cannot be used for official purposes unless the owners release them for use by everyone ; toxaphene is a good example of this procedure.

The aim in selecting a short name for a chemical is to provide an easily spoken, written, and memorized term that has no proprietary significance and which will refer to a pure chemical containing no additional material contributing to the biological effects. It is well to remember that commercial names, ostensibly referring to one active ingredient, are sometimes found to cover other active ingredients as well as, or even in place of, the one expected. The term selected must not lend itself to confusion with any proprietary name, whether for the same or another product, and, to distinguish it from proprietary names, it is written or printed with a small initial letter. A number of pesticides, especially herbicides, are marketed as various salts or esters according to the circumstances under which they are to be used ; in these cases the chemical name of the combining substance must be added in brackets after the common name, e.g. DNC (sodium), dinex (*cyclo*hexylamine).

Two parts of the list have so far been prepared, under the general title ' Recommended common names for pest control products. British Standard 1831 '. Part 1 appeared in 1952, and Part 2 has been approved and is due out in the spring of 1953. They cover four classes of pesticides : insecticides (including repellents, acaricides, and nematocides), fungicides, herbicides, and rodenticides, and give the reasonable chemical names (in one case there are eleven of these !), the structural formula (where known), and other names, including initials, in common use, but not proprietary names. Below is given the common name and the recommended chemical name of each compound so far listed ; if an alternative abbreviation is in common use, this has been added in brackets after the chemical name.

Class.	List No.	Common name.	Chemical name.
1. Insecticides.			
Chlorinated hydrocarbons	101	BHC (mixed isomers)	1 : 2 : 3 : 4 : 5 : 6-hexachloro*cyclo*hexane.
	102	*gamma*-BHC	gamma-isomer of above.
	103	chlordane	2 : 3 : 4 : 5 : 6 : 7 : 10 : 10-octachloro-4 : 7 : 8 : 9-tetrahydro-4 : 7-*endo*methyleneindan.
	104	DDT	mixture, mainly 105.

Class.	List No.	Common name.	Chemical name.
	105	*pp'*-DDT	1 : 1 : 1-trichloro-2 : 2-di(*p*-chlorophenyl)ethane.
	110	heptachlor	1(9) : 4 : 5 : 6 : 7 : 10 : 10-heptachloro-4 : 7 : 8 : 9 (1)-tetrahydro-4 : 7-*endo*methyleneindene.
	117	methoxychlor	1 : 1 : 1-trichloro-2 : 2-di(4-methoxyphenyl)ethane.
	113	toxaphene	a chlorinated camphene.
Organophosphorus compounds, including 3 systemics.	116	malathon	S-(1 : 2-dicarboethoxyethyl) O,O-dimethyl dithiophosphate (Compound 4049).
	111	parathion	O,O-diethyl O-*p*-nitrophenyl thionphosphate.
	115	dimefox	bis(dimethylamino)fluorophosphine oxide.
	118	mipafox	bis(mono-*iso*propylamino)fluorophosphine oxide.
	112	schradan	bisdimethylaminophosphonous anhydride.
Ovicides.	106	dinex	2-*cyclo*hexyl-4 : 6-dinitrophenol (DNOCHP).
	107	dinosam	2-*sec*-amyl-4 : 6-dinitrophenol (DNAP).
	108	dinoseb	2-*sec*-butyl-4 : 6-dinitrophenol (DNBP).
	109	DNC	2-methyl-4 : 6-dinitrophenol (DNOC).
Pyrethrin analogue.	114	allethrin	mixed *cis* and *trans* *dl*-chrysanthemum monocarboxylic esters of *dl*-2-allyl-4-hydroxy-3-methyl-2-*cyclo*penten-1-one.
Acaricide.	119	oxythane	bis(4-chlorophenoxy)methane (DCPM).
	(The organophosphorus compounds are also acaricidal).		
2. Fungicides.			
	201	ferbam	ferric dimethyldithiocarbamate.
	202	nabam	disodium ethylenebisdithiocarbamate.
	203	thiram	tetramethylthiuram disulphide (TMT, TMTD, TMTDS).
	204	zineb	zinc ethylenebisdithiocarbamate.
	205	ziram	zinc dimethyldithiocarbamate.
	206	technazene	2 : 3 : 5 : 6-tetrachloronitrobenzene (TCNB).
3. Herbicides.			
	301	2,4-D	2 : 4-dichlorophenoxyacetic acid.
	302	MCPA	2-methyl-4-chlorophenoxyacetic acid.
	303	propham	*iso*propyl N-phenylcarbamate (IPPC).
	304	proxan (sodium)	sodium *iso*propyl xanthate.
	305	2,4,5-T	2 : 4 : 5-trichlorophenoxyacetic acid.
	(The insecticides 106, 107, 108, and 109 are also herbicides).		
4. Rodenticides.			
	401	antu	1-naphthylthiourea.
	402	warfarin	3-(α-acetonylbenzyl)-4-hydroxycoumarin.

This list will be added to as occasion demands, and the next issue may well contain a short name for the fungicide quoted in the opening paragraph. The committee will have to be very ingenious if short names of sufficient distinction are to be found and the difficulty associated with use of initials is to be avoided.

Summary.

An outline is given of the new arrangement whereby official common names are given to pesticides. A classified list is provided of those names approved up to the end of 1952.

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THE JOURNAL OF HORTICULTURAL SCIENCE

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The current volume XXVIII (1953) contains some 28 papers, of which 13 have been contributed by Long Ashton and East Malling. The subjects discussed include rootstock/scion compatibility, fruit development in relation to plant hormones, studies in iron, zinc and copper deficiencies, the predators of the Fruit Tree Red Spider Mite, the control of Apple Sawfly, and spraying experiments against Apple and Pear Scab.

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